ENVIRONMENTAL QUALITY

TWENTIETH Annual Report

The Council on Environmental Quality

The Executive Office of the President

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ENVIRONMENTAL QUALITY

The Twentieth Annual Report of
the Council on Environmental Quality together with
The President's Message to Congress

The President's Message

TO THE CONGRESS OF THE UNITED STATES:

The people of this country share a deeply rooted love and concern for the environment. We have been blessed with a wealth of natural resources that enrich our physical and spiritual lives, and throughout our history we have recognized our responsibility to protect those resources for the generations to come.

Even as the pioneers traveled west to civilize a wild and seemingly endless frontier, there were Americans who understood that the Nation's natural resources had to be conserved for the future. In 1871, long before all of the continental states were incorporated into the Union, two million acres were set aside to create Yellowstone, our first national park.

The consequences of thoughtless exploitation of our natural resources began to be noticed more than a century ago. In 1908, President Theodore Roosevelt convened at the White House a national conference on conservation, where he said: "The wise use of all our natural resources, which are our national resources as well, is the great material question of today." That conference was a historical landmark in the development of public policy to protect and manage this country's natural resources.

Our national environmental ethic was expressed with particular clarity and conviction in 1970. On the first day of that year, President Nixon signed the National Environmental Policy Act, which created the Council on Environmental Quality and incorporated environmental awareness into the planning processes of the Federal Government. On the last day of 1970, the President signed the Clean Air Act, the Nation's first comprehensive environmental protection law. During that year, the Environmental Protection Agency and the National Oceanographic and Atmospheric Administration were established. And on April 22, 1970, millions of Americans voiced their environmental hopes and concerns on Earth Day.

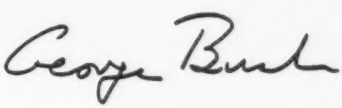
This long national tradition of natural resource stewardship and environmental protection continues today, and in many ways it is stronger than ever. During the last 20 years we have built on the work begun in 1970, and the results have been remarkable. Possible effects on the environment are now weighed carefully whenever Federal agencies plan major actions. Our scientists have developed pollutant detection and control technologies that are far more effective than anything available in 1970. Environmental laws are now enforced, and environmental crimes punished, at every level of government, and enforcement officials have more legal and technical tools at their disposal than ever before. Besides spending billions of dollars a year to capture pollutants before they enter the air or water, American companies are beginning to invest in production materials and processes that generate much less pollution. And governments around the world are working together in unprecedented ways to solve pollution problems that affect the global quality of life.

We can be proud of our environmental track record. In many ways we have set an example for the rest of the world, and other nations continue to look to the United States for environmental leadership. Over the past year, as the countries of Eastern Europe shook off their chains and took charge of their own political and economic lives, they turned to us for help in reversing decades of environmental neglect.

This 1989 Report to the Congress on Environmental Quality is a retrospective—a look back at the ways our national environmental ethic has evolved over the past 20 years. And in looking

back, the report also suggests a fair measure of hope for the future.

We have not solved all our environmental problems. Some we have only begun to understand. But over the past 2 decades we have proven to ourselves, and to the rest of the world, that we are willing to act on our beliefs. If the best prophet of the future is the past, as Lord Byron once wrote, then our children and grandchildren can look forward to the same good health, clean environment, and abundant natural resources that so many Americans have been so fortunate to share.



THE WHITE HOUSE

EXECUTIVE OFFICE OF THE PRESIDENT

COUNCIL ON ENVIRONMENTAL QUALITY

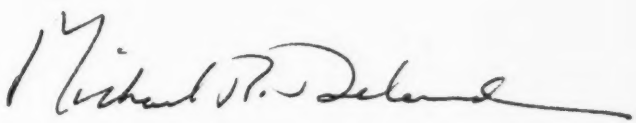
WASHINGTON, DC 20500

Letter of Transmittal

The President:

Sir: The Council on Environmental Quality herewith submits its Environmental Quality Report for the year 1989 in accordance with section 201 of the National Environmental Policy Act of 1969 (42 U.S.C. 4341).

Respectfully,



Michael R. Deland
Chairman

From the Chairman

This is a very special year for the staff at the Council on Environmental Quality. While we are celebrating CEQ's own 20th birthday, we are joining with the rest of the country to celebrate the 20th anniversary of all the events that marked 1970 as a watershed in the history of the environmental movement in the United States.

Birthdays and anniversaries are by definition times of reflection. They remind us of the past, of what we once were. But our commemorations of the past are also comments on the present, because when we look back at the turning points in our lives, we measure how far we have come. To that end, I asked Russell Train, CEQ's first chairman, for his views on the progress that CEQ has made over the past two decades. His remarks are included as a forward to this report.

This year's annual report to the Congress departs from past practice in the sense that it does not discuss in detail the environmental issues and trends of the moment. Instead, it is a retrospective, an evaluation of the distance traveled since 1970. It is important to remind ourselves, as we engage in our daily debates over the nuance of evolving environmental policy, that this country has come a very long way in the past 20 years.

This year's CEQ Annual Report is also different in another sense. Because the events of 1970 emphasized environmental quality and pollution control, this 20-year retrospective necessarily emphasizes them as well. The lack of attention to natural resource issues is a function not of disregard, but of history.

The subject matter of this report was selected to exemplify the different ways that environmental policy has evolved over the past two decades. Other examples could have been used to make the same point. There is little mention here, for instance, of environmental economics, yet the integration of environmental and economic concerns is surely one of our most notable achievements. Over the past two decades the presumed linkage between economic growth and environmental degradation has been broken. For example, since 1970 the U.S. economy has grown by about 70 percent in real terms, while energy use and CO_2 emissions have stabilized.

We know now that a growing economy and a clean environment can go hand in hand. We are in the vanguard of what President Bush has called "an early new way of thinking to achieve both while compromising neither, by applying the power of the market place in the service of the environment." This maturation in our thinking is evidenced by the continuing shift in emphasis from the "command and control" approach that regulates pollutants at the end of the pipe to a newer focus on preventing pollution in the first place.

In this country, the President has proposed a new Clean Air Act that sets environmental targets, but gives industry the leeway—and the incentive—to hit those targets in the most efficient way. In Europe, countries downwind of industrial pollution are beginning to pay for controls in other countries, because such investments bring substantial environmental benefits to the donor countries. Few people in 1970 would have predicted that market incentives would play such an important role in environmental protection 20 short years later.

Thus the material in this report should be considered illustrative, not exhaustive. It illustrates how far we have come and, by extension, how far we have yet to go. It illustrates the importance that the American people attach to the quality of the environment. It illustrates the debt that we all owe to the people who worked so hard for the environment in 1970. And it fortifies our resolve to work that much harder to protect the environment for future generations.

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This report was written and assembled by many hands, and I very much appreciate their work. Special thanks go to the following individuals:

- **Chapter One:** Tom Super, who also served as the overall manager for this report

- **Chapter Two and related NEPA materials:** Carl Bausch, Ed Yates, Dinah Bear, and Sara Nero of CEQ

- **Chapter Three:** Lisa Gandy and Kent Thornton of FTN Associates

- **Chapter Four:** Dave Alexander and Larry Buc of ICF, Inc., with assistance from Prof. Albert Rabbat of Tufts University and Dale Curtis of CEQ

- **Chapter Five:** Barry Walden Walsh, independent consultant, with review assistance from Lisa Jorgenson

- **Chapter Six:** Christine Ervin, Fran Irwin, Eric Hostetler, Bill Silagi, and Barbara Rodes from The Conservation Foundation, with assistance from Mary Holland of CEQ

- **Chapter Seven:** John Cohrssen of CEQ, with assistance from Jonathan Elkind of CEQ and Konrad von Moltke, Chaplin Barnes, Scott Hajost, and Andy Sens

- Larry Silverman, independent consultant, with assistance from Robin O'Malley of CEQ

In addition, I want to thank Brenda Heffernan, Kim Chastain, Kathleen Gallagher, and Donna Connell for administrative support; JT&A, Inc., for their professional typing, editing, layout, and production services; and Barry Walden Walsh for editing and proofreading. Mike Schneider and Caesar Jackson of the U.S. Information Agency assisted us with graphics, and Carroll Curtis assembled the statistical appendix. The photos used in this report are courtesy of EPA's Steve Delaney and the Associated Press. Finally, Tom Super demonstrated a rare blend of patience and tenacity in managing the preparation of this report, and I am especially grateful for his efforts.

Foreword

by

Russell E. Train
First Chairman of the Council on Environmental Quality

In February 1970 President Nixon introduced Gordon McDonald, Robert Cahn, and me to the White House press as the first members of the Council on Environmental Quality. At that time the President declared that the Council would be the environmental conscience of the nation.

Heady stuff, particularly at a time when the first high tide of environmental concern and activism was approaching its peak. The first Earth Day was just two months away. Of course, the President's prescription seemed to imply that the Council would act as a "bully pulpit" from which to criticize and exhort American society and institutions, including other government agencies, in the interest of environmental protection. In practice, that was not a role that the Council could appropriately fill. As part of the Executive Office of the President, ours was necessarily an "inside" operation, one that depended less on high public visibility and more on quietly mobilizing the federal bureaucracy, making the system work, and using the clout that Presidential backing gave us. And, inevitably, as the Environmental Protection Agency came into existence at the close of 1970, it was EPA that assumed the more visible role as the public protector of the environment.

Nonetheless, I still contend that the Council played an absolutely seminal role in the development of the federal government's environmental policy and program, both domestically and internationally.

The National Environmental Policy Act, in addition to establishing CEQ, also mandated the environmental impact statement process, and to CEQ fell the task of translating that mandate into an effective government-wide system. The Council developed and issued EIS guidelines for the guidance of each of the principal federal agencies and then worked closely with them, cajoling and pushing as needed, to see to it that effective arrangements were established and then carried out by the agencies themselves. In some cases, it was an uphill struggle! Bureaucracies, whatever system of government is involved, do not easily accept change, let alone revolution, in the way they do business.

There had been an effort on the part of some agencies to make CEQ itself responsibile for conducting environmental impact analyses for all relevant federal actions. A procedural nightmare would have resulted, and we early saw the need for and insisted on placing the full EIS responsibility squarely upon the operating agencies themselves. For several years, the CEQ staff monitored each agency's EIS performance on a project-by-project basis, a heavy administrative burden that eventually was shifted largely to EPA. It has been said that the EIS process brought about nothing less than a revolution in the way federal agencies make decisions, and it was CEQ, more than any other factor, that made that revolution a reality.

Having said this, I want to acknowledge the critical impact of citizen lawsuits in putting teeth into the EIS process. Citizen involvement from the beginning has been a crucial element in perfecting that process.

The President's annual environmental message to the Congress (1970, 1971, 1972, and 1973) early became the vehicle for a variety of legislative and other initiatives, and the White House gave CEQ responsibility for developing the substantive contents of each message. In practice, this responsibility put CEQ at the center of an ongoing interagency process that resulted in what I believe to have been the greatest outpouring of legislative and executive initiatives dealing with a single subject area in our nation's history.

In addition to the legislative initiatives, CEQ played an active role in stimulating significant executive actions, many of which were first announced in the President's annual environ-

mental message. These included such diverse matters as the banning of the use of DDT on all public lands, the regulation of off-road vehicles on public lands, federal procurement of recycled materials, the auto fuel economy testing program, and the issuance of energy efficiency guidelines for federal buildings. In a particularly dramatic move, the President acted on the CEQ recommendation to halt construction of the Cross-Florida Barge Canal, declaring that the environmental damage exceeded the claimed economic benefits of the project.

While CEQ was at the center of domestic environmental policy, it also played a vital role in the rapidly emerging international environmental field. It led the negotiations on the U.S. side that produced the Great Lakes Water Quality Agreement with Canada, the Ocean Dumping Convention, the U.S.-Soviet environmental agreement, the Convention on the International Trade in Endangered Species of Fauna and Flora (CITES), and the World Heritage Convention. The Soviet agreement, CITES, and the World Heritage Trust Convention all had their inspiration largely from within CEQ itself.

It was likewise the Council's initiative that opened bilateral environmental cooperation with Japan and West Germany. We led the U.S participation in the NATO Committee on the Challenges of a Modern Society, the environmental committee of the Organization for Economic Cooperation and Development (OECD) in Paris, and the joint U.S.–Soviet environmental committee. The latter was by far our largest and most active bilateral environmental undertaking. As chairman of the Council, I led the U.S. delegation to the 1972 U.N. Conference on the Human Environment in Stockholm–a watershed event in the evolution of international environmental affairs.

In its work in such international bodies as OECD, the Council was a leading proponent of the "polluter-pays principle," namely, that industry should bear the cost of abating its own pollution and that such costs should not be met by government subsidy. The principle was an important one to help avoid competitive disadvantages for U.S. industry, and we gained its general acceptance in the policies of other nations, if not always in actual practice.

In the early and mid-1970s as environmental issues began to emerge on the international scene, there was no question that

the United States was perceived as the world leader in addressing these issues. Our own national experience in aggressively attacking domestic environmental problems was the essential underpinning for that leadership role. Our credibility could not easily be questioned in that respect. CEQ had a principal role in carrying that national experience, both legislative and administrative, into the international arena.

Without any question, the major influence of CEQ in both domestic and international environmental affairs was due, in part, to the fact that it came into existence almost a year before EPA. We were on the scene first. At the same time, the Council played a significant role in 1970 in the discussions within the Administration as to the proper way to structure the environmental management functions of the federal government. We were strongly of the view that these functions could best be exercised at that time by a sharply focused, highly visible, independent agency rather than by their submersion in a larger, more diverse conglomerate such as a Department of Natural Resources. As we know, the independent agency concept prevailed, and the Environmental Protection Agency came into being in December 1970.

The great surge of environmental policy initiatives that I have described had produced new institutions that required organization and management, sweeping new legislative and executive mandates that needed to be implemented, regulations that needed to be written, and international agreements that needed to be carried out. An extraordinary, comprehensive framework of environmental policies had been put into place, and CEQ had been at the heart of that endeavor. It was an endeavor that from my perhaps biased perspective represented the single greatest domestic accomplishment of the Nixon Administration.

Today, 20 years after CEQ came into existence in the first flush of national environmental enthusiasm, the Council stands on the threshold of a new era of opportunity. Public concern for environmental quality, far from being a passing fad, is greater than ever. What was once the enthusiasm of a relatively small group has now been institutionalized throughout our society. And while important progress has been made in addressing environmental problems on the domestic front over the past 20 years, new problems are emerging that urgently require atten-

tion. Globally, problems such as ozone depletion, climate change, ocean pollution, toxic wastes, the loss of biological diversity, and the destruction of tropical forests have assumed priority on the international agenda. Once again, we need to be taking hard looks at environmental policy.

It is time as well to give fresh emphasis to the development of economic incentives in the pursuit of environmental goals. While a strong regulatory program will doubtless remain the foundation of environmental protection, the fact that there are literally millions of sources of pollutants inevitably places limits on the effectiveness of enforcement. It makes sense to try to engage market forces whenever practical.

There is growing recognition of the importance of maintaining biological diversity and of promoting sustainable agriculture, sustainable forestry, and sustainable development in general. Yet, in practice, these objectives tend to be pursued more often than not in the context of the Third World, particularly in relation to the programs of the U.S. Agency for International Development and the multilateral development banks. Sustainable development and biological diversity within the United States could well be the focus of major CEQ efforts. Putting our own house in order in these respects will lend credibility to U.S. international initiatives and will address very real needs at home. Such issues tend to be "cross-cutting" insofar as the functions of federal agencies are concerned and, thus, particularly appropriate for CEQ involvement.

Environmental issues typically cut across the responsibilities of more than one agency. Indeed, some of the most complex of these issues lie at the interface between environmental and energy, agricultural, transportation, and economic interests. As part of the Executive Office of the President, the Council is ideally situated to be helpful in the development of creative policies in such areas.

With the President's proposal to elevate EPA to departmental status, a proposal I heartily endorse, it seems certain that strengthening of the federal government's overall institutional framework for environmental policymaking and management will follow. Given adequate resources, CEQ can and should play a significant role in that development. The opportunities abound.

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ENVIRONMENTAL QUALITY

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April 22, 1970

On April 22, 1970, the nation witnessed a remarkable outpouring of widespread, public concern: several million Americans in communities all across the country took part in an event called Earth Day. On that day environmental education programs were presented at thousands of grade schools; the National Education Association estimated that 10 million school children participated. Teach-ins were held at several thousand high schools and colleges, and hundreds of thousands of students collected litter from parks, city streets, and suburban neighborhoods. Mass demonstrations were held in cities like Philadelphia, Chicago, New York, and Washington, D.C. Automobile traffic was banned from a part of downtown Manhattan, and Congress adjourned to allow members to speak at environmental rallies across the country. As The Washington Post reported, on Earth Day millions of Americans "demonstrated . . . their practical concern for a liveable environment on this earth."

CHAPTER 1

Twenty Years of Change

Twenty years ago, in August of 1970, the newly created Council on Environmental Quality published its first Annual Report to the Congress. The first chapter of that report began: "Historians may one day call 1970 the year of the environment." Judged from a vantage point of two decades later, that prediction has come true. There can be little doubt that 1970 was the single most important year in this country's environmental history.

During 1970 the widespread environmental concerns and protestations that marked the 1960s began to be translated into the national environmental legislation that marked the 1970s. On the first day of 1970, President Richard Nixon signed the National Environmental Policy Act (NEPA), a law with an extraordinarily broad purpose: "To declare a national policy which will encourage productive and enjoyable harmony between man and his environment." In essence, NEPA was enacted to ensure that the federal government, when it planned any significant action, would consider all possible deleterious effects on environmental quality. Thus NEPA was intended to inculcate into the federal government, in all its policies, regulations, and laws, a practical environmental ethic.

Later in the year, several existing federal offices and programs were reorganized to "effectively ensure the protection, development and enhancement of the total environment itself." In his message to Congress on July 9, 1970, describing this reorganization, President Richard Nixon wrote: "Our national government today is not structured to make a coordinated attack on the pollutants which debase the air we breathe, the water we drink, and the land that grows our food. Indeed, the present governmental structure for dealing with environmental pollution often defies effective and concerted action." The President proposed to pull together environmentally related federal activities that had sprung up in piecemeal fashion over the years, and to combine them into systematic organizations that would be far more effective. Thus by the end of 1970 both the Environmental Protection Agency (EPA) and the National Oceanographic and Atmospheric Administration (NOAA) were born.

The EPA had no sooner been created than it was handed its first major responsibility; sweeping amendments to the Clean Air Act were signed on December 31, 1970. This new law amended federal air pollution legislation enacted during the 1960s and also significantly expanded its scope. For the first time a federal environmental law attempted to protect an environmental resource—air quality—in a comprehensive way. Among other things, the 1970 Clean Air Act established nationwide air quality standards to protect health and welfare standards, and it required all states to write formal plans describing how they would attain and maintain those standards. The Clean Air Act of 1970 also required that certain new sources of pollution nationwide—like new automobiles and power plants—meet stringent environmental performance standards. But most important of all, the new Clean Air Act set an example. The people of the United States expected the federal government to play a major role in protecting the environment, and the Clean Air Act of 1970 demonstrated just how extensive that role would be.

Of all the signal environmental events of 1970, the one that most involved the public was Earth Day, April 22, 1970. On that day millions of Americans actively expressed their concerns for the quality of the environment. Through teach-ins, protests, speeches, and neighborhood cleanups, people all across the country conveyed their sense that something had to be done.

Many members of Congress took part in Earth Day activities, responding, as *The Washington Post* described it, "to what they sense as the national mood for cleanup by embracing the environmental issue like motherhood."

The enactment of NEPA, the establishment of EPA and NOAA, and the sweeping amendments to the Clean Air Act show how carefully the national government was listening to the concerns of the American people. In fact, that may be the reason that 1970, in hindsight, stands out as an important historical landmark. For during that year the concerns and aspirations of millions of Americans, from school children to the Congress, seemed to resonate in unison. The country needed to act, and act it did. Whether through public demonstrations or national legislation, Americans from all parts of the country and from all walks of life gave voice to their deeply held environmental convictions. And they set in motion a chain of events that has changed the national consciousness and redefined the way Americans interact with the natural world.

The Meaning of 1970

Seen in the context of the ensuing two decades, the importance of environmental events in 1970 seems clear and unambiguous. But at the time, their long-term significance was much debated. Some of the government officials who participated in Earth Day wondered aloud whether such environmental activism would persist into the future. According to *The New York Times*, Secretary of the Interior Walter Hickel observed the day after Earth Day: "I am optimistic about Earth Day and I hope it will not be the finale following one year of increased environmental awareness." *The Washington Post* quoted a Maryland Congressman after he gave an Earth Day speech: "The day's a good thing. . . . But we're really fighting human nature. I don't know how much of this can be sustained." And in a front-page story on

Earth Day *The Washington Post* wondered: "The next several months will show whether Earth Day was the high water mark of another short-lived protest movement or the manifestation of a new political coalition that must be reckoned with for years to come."

That some people at the time doubted the long-term viability of the environmental movement is understandable given the national mood. During the 1960s large public demonstrations intended to shape public policy had been common; the American public had witnessed a succession of demonstrations over poverty, civil rights, and the war in Vietnam. The public protests against environmental degradation may have been difficult to differentiate from other kinds of well-publicized civil demonstrations.

Moreover, the environmental movement in 1970 was demanding something that no nation had ever done before: the enactment of comprehensive, national legislation to protect the environment. Implicit in that goal—whether explicitly stated or not—was a call for fundamental change in the American economic calculus. More and more people were beginning to appreciate clean air and clean water as precious resources that were neither free nor inexhaustible. Consequently, no person or business or community could appropriate those resources for their personal use to the detriment of others.

The economic implications of those early calls for environmental protection were not overlooked. In fact, the potentially huge economic costs of pollution control—postulated in terms of jobs lost and economic growth foregone—may have been a major reason why some people wondered whether the environmental movement would persist. In 1970 it was not unusual to hear arguments postulating irrevocable links between economic growth and the generation of pollution, and warning that environmental protection would cost jobs. For example, on the Sunday before Earth Day 1970, *The New York Times Magazine* printed an article in which that argument was made explicitly: "If we start with the proposition that the growth of production is the underlying cause of pollution, which has merit as a starting point, the only way we can get less growth in production, if we want it, is to have more of our labor force idle more of the time."

In the face of all this—the prior decade of protests, the lack of any historical model, the economic forebodings—it is not surprising that some people wondered if the events of 1970 would have any lasting meaning. It is not surprising that in 1970 some people wondered how much different the world of 1990 would really be.

And it is not unreasonable for people in 1990 to ask much the same question. At a distance of 20 years, it may be useful to reflect back and ask: To what extent have the hopes voiced in 1970 been fulfilled? To what extent has the nation succeeded in meeting the expectations that were raised so high in 1970?

For Better or Worse

In the two decades that followed the singular events of 1970, the nation's growing concern for the environment manifested itself in a dozen major—and several dozen minor—federal environmental laws. By 1989 the federal government had acquired regulatory responsibilities addressing air quality, water quality, drinking water, solid wastes, hazardous wastes, medical wastes, pesticides, toxic substances, endangered species, occupational safety and health, coastal zones, ocean pollution, and the upper atmosphere, among others.

One way to measure the nation's environmental progress since 1970 would be to look at 20-year data trends in those areas. Trends in pollutant emissions, biodiversity, and human health clearly are important measures of the relative success or failure of national efforts to protect the environment.

However, such trend data give only partial answers, and even those partial answers tell an inconsistent story. The nation's success at fulfilling the promise of 1970—as measured by environmental trends data—has been mixed. After two decades of unprecedented environmental activism, some facets of

the environment show remarkable improvement, while the quality of others has deteriorated sharply.

For example, in response to the Clean Air Act of 1970, the Environmental Protection Agency (EPA) set national standards for the six most prevalent air pollutants: sulfur dioxide, nitrogen oxides, carbon monoxide, particulates, hydrocarbons, and lead. The federal and state governments then took a range of actions designed to reduce emissions of those pollutants so that the national health standards would be met nationwide.

For some of those common air pollutants, the 20-year record has been extraordinarily successful, especially in the case of lead. Between 1970 and 1987, total annual emissions of lead nationwide declined by 96 percent, from 203.8 million to 8.1 million tons, mainly due to the gradual phase-out of leaded gasoline. Today virtually all areas in the United States meet the national health standard for lead.

The United States also has made substantial progress in controlling sulfur dioxide (SO_2) and particulate matter (PM). Prior to 1970, emissions of SO_2 and PM had been increasing rapidly. But, between 1970 and 1987, total annual national emissions of SO_2 dropped by 28 percent, from 28.2 million to 20.4 million tons; particulate emissions declined by 61 percent, from 18.1 million to 7.0 million tons. As of 1987, most areas of the country met the national health standards for SO_2 and particulates.

The nation's record in controlling nitrogen oxides (NO_x), ozone, and carbon monoxide (CO) is mixed. For example, total national emissions of NO_x increased almost 8 percent between 1970 and 1987, rising from 18.1 million to 19.5 million tons, while the pre-1970 rate of growth dropped sharply. Despite the increase in total NO_x emissions, almost all areas in the country meet the national health standard for NO_x.

Total national hydrocarbon and CO emissions, which also had been growing rapidly, dropped by 28 percent and 38 percent, respectively, over the same period. Yet national health standards for both pollutants are still being exceeded in many U.S. cities. During 1989 EPA reported that approximately 110 U.S. urban areas failed to meet the national ozone standard, and about 50 areas did not meet the CO standard.

Despite continued air pollution problems in many places, primarily cities, the country's efforts to protect air quality have

been substantial. Not only have total annual emissions of the most common air pollutants declined or remained fairly constant over the past two decades, but they have done so in spite of strong economic and population growth.

Since 1970 the population of the United States has grown by almost 22 percent. In 1970 the U.S. population totalled 205 million. Sometime during 1990, it will pass 250 million.

Over the same period, the U.S. economy has grown more than three times as fast as the population. In 1970 U.S. gross national product (GNP) was $2.42 trillion (measured in 1982 dollars). The Council of Economic Advisors estimates that U.S. GNP in 1989 was $4.17 trillion (measured in 1982 dollars), an increase of 72 percent. At least as far as the six most common air pollutants are concerned, the United States clearly has severed the linkage between economic growth and pollution growth, a linkage that seemed obvious and unbreakable to many people in 1970.

The nation's progress in controlling air pollution is especially noteworthy when evaluated in the context of skyrocketing growth in automobile use over the past 20 years. In 1970 the number of automobiles registered for use on U.S. roads was 89.2 million; by 1989 that number had jumped 56 percent to 139 million. Moreover, those automobiles were being driven many more miles. Between 1970 and 1987, the total vehicle miles traveled annually in this country rose from 920 billion to 1,313 billion, an increase of almost 48 percent.

There is no doubt that more needs to be done to control air pollution—especially CO and hydrocarbons—in this country. Millions of Americans still experience episodes of unhealthy air, and the Administration is committed to strengthening the Clean Air Act through the most cost-effective means to address this concern. But an evaluation of environmental progress must consider not only the current quality of the environment, but also what that quality would be had no action been taken. And undoubtedly, without the existing Clean Air Act, even intransigent problems like ozone and CO would have been very much worse.

If, on the other hand, the viability of wetlands and estuarine ecosystems is used to measure environmental progress, the nation's track record over the past two decades is less impressive. In 1970 the United States contained about 99 million acres

of wetlands. No one knows exactly how many acres have been lost since then, but it is estimated that between the mid-1950s and mid-1970s losses exceeded 450,000 acres per year. Even though annual losses probably dropped after that time, wetlands destruction has continued at an unacceptable rate. In response to this problem, the President has announced that he is committed to the eventual goal of no net loss of wetlands. The President has directed a Domestic Policy Council task force to provide recommendations on wetlands policy following a series of public meetings this year.

Moreover, the quality of some coastal waters and estuaries apparently has declined over the last two decades. Between 1971 and 1985, shellfish harvest restrictions resulting from environmental contamination increased 14 percent to 7.5 million acres; by 1985 approximately 40 percent of the nation's shellfish beds were closed for some or all of the season. Closures were caused by environmental pollution ranging from inadequate or overwhelmed sewage treatment plants to urban water runoff to contamination from feedlots and other agricultural operations. Most recently, coastal beach closings and oil spills have focused public attention on coastal water quality.

Trends in waterfowl populations, which rely upon wetlands during breeding and migration, indicate the declining health of wetlands. Populations of mallard ducks have dropped by about 40 percent during the past 20 years. Mallards generally use a wide range of habitat for breeding, but filling, draining, and encroachment on wetlands has overtaxed even that species' ability to adapt. In short, both the quantity and quality of U.S. wetlands appear to have declined over the past two decades.

Population growth along U.S. coasts contributes to pressures on water quality and the decline of wetlands in many areas. In 1989, in fact, approximately 80 percent of the U.S. population lived in coastal counties (including those bordering the Great Lakes). Population growth usually leads to more polluted water runoff, the filling or draining of wetlands for development, and overtaxed wastewater treatment systems. Thus population growth—together with associated economic growth—contributes not only to direct wetlands losses, but also to a deterioration in water quality and the health of those wetlands that remain.

Wetlands losses result from other causes as well. Agricultural practices contributed to the vast majority of wetlands losses from the 1950s to the 1970s, and they continue to cause additional losses.

Other environmental trend data illustrates both the successes and shortcomings of national environmental protection efforts since 1970. For example, between 1972 and 1986 the number of Americans served by secondary wastewater treatment facilities, or better, increased from 85 million to 127 million. Consequently, the water quality in many stream and river segments in this country is much improved. On the other hand, concentrations of carbon dioxide (CO_2) in the atmosphere have increased at an average rate of about 1.4 percent a year since 1970, contributing to rising concerns about possible global climate change.

Taken as a whole, environmental trends data suggest that over the past two decades the United States has been fairly successful in protecting and improving environmental quality when the existence of a problem has been widely recognized and the sources of the problem well defined. In cases where general recognition of a problem emerged slowly over time, or where the sources of a problem were diverse and widely dispersed, progress has been slow and painful, at best.

Other Measures of Progress

Despite the mixed success indicated by environmental trends data, the environmental ethic of the American people clearly has evolved dramatically since 1970. Over the past 20 years the nation's attitude toward environmental pollution and the tools it uses to control it have changed in some extraordinary and fundamental ways.

For example, the enactment of the National Environmental Policy Act has caused environmental considerations to be incorporated into planning processes throughout the federal govern-

ment. Over the years, legally required environmental assessments have been criticized for their complexity and costs, and the applicability of NEPA outside the territorial United States is still subject to debate. But the actions of federal agencies undoubtedly have been changed in very real ways because of NEPA, and those changes have resulted in improved environmental quality. (See Chapter 2.)

In 1970 very little environmental monitoring was conducted in this country, and environmental data collection in different parts of the country was neither comprehensive, coordinated, nor long-term. In fact, most environmental data were collected in response to specific problems; government officials were forced to react to environmental degradation, because they had no capacity to anticipate it. Since then, the national investment in environmental data collection has expanded considerably, and in some cases it is being coordinated through the cooperative activity of state, federal, and international governments. (See Chapter 3.)

Twenty years ago many Americans were convinced that environmental pollution needed to be controlled, but the science and technology needed to identify, assess, and control such pollution was almost nonexistent. Scientific and technological advances over the past 20 years have changed the way Americans live, and such progress has been especially notable in the environmental arena. (See Chapter 4.)

Unlike 1970 environmental pollution today is considered not only harmful and irresponsible, but—in many instances—criminal as well. Environmental laws are enforced now at every level of government, by a number of federal, state, and local agencies, and with a much-expanded array of tools. Although violations of environmental laws continue to present problems, law enforcement officials today are much better equipped to address them. (See Chapter 5.)

One of the most fundamental changes that has occurred over the past 20 years is the response of American businesses to their environmental responsibilities. Many corporations today are interested not simply in their legal responsibilities to control pollution before it escapes to the environment, but in the broad corporate benefits that attend efforts to reduce pollution at its source. Widespread efforts to redesign manufacturing processes,

substitute less harmful production materials, and recycle wastes are beginning to play a major role in protecting the environment. (See Chapter 6.)

In 1970 the need for international cooperation to solve emerging global pollution problems was becoming apparent. Since then, international efforts to assess and respond to problems like stratospheric ozone depletion, global climate change, desertification, transboundary air pollution, loss of species and habitats, and international transportation of hazardous wastes have proliferated. (See Chapter 7.)

The kinds of progress described above have benefitted the varied ecosystems in this country. A good example of the results of environmental policy over the past 20 years is the Great Lakes. For in that magnificent fresh-water resource can be seen many of the benefits of national—and international—pollution control efforts. The Great Lakes also demonstrate the kinds of environmental problems still remaining. (See Chapter 8.)

The environmental changes that have occurred in this country over the past 20 years do not suggest that a pollution-free world is in sight. If recent history is any indication, the United States—and the rest of the world—may very well be worrying in 2010 about environmental problems unforeseen today.

Yet the experience of the past two decades also suggests that Americans in 2010 will respond to environmental problems with energy, creativity, and a deep-seated sense of responsibility for future generations. Americans believe strongly that environmental quality is an essential component of their long-term health and economic prosperity. They have demonstrated that they have the will to protect environmental quality and the capacity to act. The lessons of the past 20 years can give all Americans hope for the future.

May 24, 1989

On May 24, 1989, Oregon Federal District Court Judge James M. Burns dissolved a long-standing injunction against spraying forests of the Pacific Northwest with 2,4-D and other herbicides. That action brought to a close an emotion-charged legal battle that had pitted the Northwest Coalition for Alternatives to Pesticides (NCAP), the Oregon Environmental Council, and other organizations against the USDA/Forest Service and the DOI/Bureau of Land Management. The two sides had battled for 13 years over federal plans to control unwanted vegetation on public lands using herbicides whose chronic toxicities had been linked to malignant lymphoma, liver damage, and birth defects.

The final agreement was not reached through a hail of legal briefs or other procedures normally associated with lawsuits. Instead, it was achieved amicably through a mediated agreement that allowed the federal government to use some of the herbicides in question, but with additional monitoring and public safeguards.

Alleged violations of the National Environmental Policy Act (NEPA) by federal agencies had provoked the 13 years of litigation, yet ironically the act was also responsible for bringing about the mediated settlement. NEPA provided a forum — the environmental impact statement process — in which private citizens and the federal government met together in a spirit of cooperation to work out their differences.

CHAPTER 2

The National Environmental Policy Act

The enactment of the National Environmental Policy Act of 1969[1] (NEPA) is now seen to be the first step in 20 years of remarkable environmental activism in the United States. It certainly was a major statement of this country's environmental ethic. Yet the real-world contribution of NEPA to environmental quality is sometimes questioned and often misunderstood. Because NEPA was not designed to control specific kinds or sources of pollution, its benefit to society is difficult to quantify. The act was designed primarily to institutionalize in the federal government an anticipatory concern for the quality of the human environment, that is, an attitude, a heightened state of environmental awareness that, unlike pollution abatement, is measurable only subjectively and qualitatively.

Yet NEPA is not simply a mandate for the federal government. It also recognizes that "each person has a responsibility to contribute to the preservation and enhancement of the environment."[2] NEPA's effectiveness, therefore, requires the diligence of

both the federal government and society as a whole, and any judgement on its performance is a reflection on the nation's overall environmental ethic.

Over the past 20 years, NEPA has nourished a growing environmental consciousness within this country, often in ways not envisioned by its sponsors in 1969. The act unquestionably has had a profound effect on attitudes within the federal government, and its influence outside the federal government is almost as impressive. And while NEPA is sometimes seen as not having lived up completely to expectations, those expectations may have underestimated the environmental pressures created by economic and population growth within this country since 1970. It may be more useful to measure NEPA in terms of the progress that has been made over the past 20 years. For during that time, the national environmental policy, which seeks to strike "a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities,"[3] has remained constant.

Prior to 1970 the vast majority of federal agencies claimed to have no authority to consider environmental factors in their planning and decisionmaking. Moreover, consideration of such factors was viewed by most agencies as an impediment to attaining their primary missions, even though those missions caused detrimental effects on the quality of the environment. NEPA changed all that by supplementing the organic charter of every federal agency with an explicit directive. It also provided a deliberative, analytical process, under which environmental values had to be factored into agency actions. As a consequence, federal agencies today almost reflexively incorporate environmental consideration into their primary decisionmaking responsibilities.

Widespread, methodical consideration of environmental values in federal agency planning and decisionmaking, while an improvement over pre-1970 practices, does not by itself fulfill the intentions of NEPA. The motivation underlying such consideration is probably a better indicator of the extent to which federal agencies have institutionalized the NEPA ethic. Motivation is difficult to gauge, but it usually reveals itself in the administrative records of proposed agency actions subject to NEPA requirements. In general, good environmental decisionmaking is charac-

terized by early and pronounced efforts to anticipate potentially disruptive influences on the environment and to avoid them. On the other hand, simple adherence to the established NEPA administrative process does not ensure that federal agencies will confront the difficult choices created by their responsibility to fulfill their primary mission and their responsibility to minimize environmental degradation. NEPA brings its richest rewards when federal agencies focus their energy on the NEPA goal and not its process.

Some administrative process is necessary to stimulate a sense of concern for environmental values, especially among agencies whose traditional mission has not explicitly incorporated such values. And the NEPA process has proven itself over a score of years to be a flexible, effective tool in developing environmental issues for consideration by government decisionmakers and the public. But process is meaningful only insofar as it is oriented toward a goal. Disconnected from its goal, process, whether or not required by law, tends to become mechanical and an end in itself. NEPA is distinguishable, purposefully so, from other environmental statutes. It targets no specific pollution sources or human health risks for treatment, prescribes formulation of no abatement techniques or remedial actions, and establishes neither milestones nor timetables for achieving its goal, a goal "concerned with principle rather than detail."[4] "Cookbook" solutions are not to be found for the difficult choices posed by the NEPA process, which seeks only to provoke thought and promote open and well-informed decisionmaking. And while federal agencies might have been less challenged had Congress refrained from adopting a national environmental policy and instead simply enacted specific laws to shape specific federal government actions, Congress chose not to do so for compelling reasons.

Historical Perspective

In the early 1960s when several committees of Congress began seriously looking into pollution problems, the nature and extent of such problems were not fully understood. In hearings and seminars that spanned several Congresses,[5] legislators learned that pollution was part of a multifaceted problem, having its roots in technologically induced change and "involving natural and social sciences, economics, and governmental and private institutions."[6] Even more vexing was the revelation that no single environmental problem could be considered separately, "that apparently isolated changes interact in unanticipated ways and that the eventual restoration of environmental quality will depend upon the solution of a series of interrelated problems, none of which can be understood in isolation from its fellows."[7] Indeed, the problem appeared so overwhelming that one observer, summarizing the views offered by several experts in the field during a joint committee hearing, was "left with a vaguely uneasy feeling that if we see the continuous complex here as one set of interconnecting realities that have to be understood as a total system, we may be broadening our interests so much that it is impossible to act on it all."[8]

The complexities and interrelatedness of the "pollution problem" caused Congress to reevaluate its practice of passing laws in response to specific episodes of environmental degradation, a practice that had led to passage of the Federal Water Pollution Control Act of 1948[9] and the Air Pollution Control Act of 1955.[10] The single-solution approach typified in those statutes was unworkable, and environmental laws in general were "floundering due to inadequate information, and misinterpretation of existing facts."[11] Many in Congress began to see the need for a comprehensive approach to the environment, one that was capable of anticipating environmentally disruptive activities and avoiding them, rather than just reacting to episodes of pollution with abatement laws.[12]

With a greater sense of purpose and perhaps some frustration, Congress began to look more closely at the federal establishment. The federal government in the 1960s was seen to be both a major cause of environmental degradation and a major source of regulatory authority. Consequently, the federal government itself became the principal focus of further efforts to fashion a comprehensive approach to the environment.[13]

An area where improvements had long been thought necessary, and for which legislation had been introduced as far back as the early 1960s, was the organization of the federal government.[14] In the 1960s environmental responsibilities were divided among 15 to 20 federal departments and agencies receiving direction and funding from two dozen different Congressional committees.[15] Reorganization of the government on a large scale, however, was not desired; nor did it "seem practical to remedy the situation by any superimposed 'czar' of environmental quality. . . ."[16] Existing institutions were thought to be up to the task, but there was no "coordinating group capable of systems analysis and broad management of federal projects."[17] The concept of an advisory council that "would exert a preemptive coordinating role and strive to prevent, rather than correct environmental degradation," although not new, took firm hold in Congress in the late 1960s.[18]

A Council on Environmental Quality was the centerpiece of H.R. 12549, introduced by Representative John Dingell of Michigan and others in February 1969. The purpose of the bill was to create "a council which can provide a consistent and expert source of review of national policies, environmental problems and trends, both long-term and short-term. Such a council would act entirely independently of the executive, mission-oriented agencies."[19] The council envisioned in H.R. 12549 would have been composed of five members and located in the Executive Office of the President. With few changes, notably the number of members, the centerpiece of H.R. 12549 became a constituent element of NEPA.

Many in Congress believed that no amount of coordination would be able to overcome the tendency for agencies to pursue their primary missions, few of which at that time included environmental quality.[20] Further, it was apparent that great potential existed for "conflicts when environmental quality is managed

by different policies, originating in conservation, agriculture, esthetics, recreation, economic development, human health, and so forth."[21] For this reason, federal agencies needed an "overall policy for the environment . . . which integrates these purposes and objectives and which provides for choice when they are incompatible . . . [mindful that] [c]hoices are not always quantitative and trade-offs are not systematic."[22]

Given the intricacies and interrelatedness of the human environment, a policy oriented toward very specific goals or objectives was seen as impractical. Thus, it was believed that "a comprehensive policy toward the environment cannot help but be philosophical rather than specific."[23]

What was to become the national environmental policy was prepared at the direction of Senator Henry Jackson of Washington, who considered the policy a means of establishing priorities and giving expression to "our national goals and aspirations . . . [serving] a constitutional function in that people may refer to it for guidance in making decisions where environmental values are found to be in conflict with other values."[24] According to Senator Jackson:

> *A properly drafted Congressional statement of national environmental policy, along with a requirement for official statements of environmental findings in federal decisions and legislative proposals, will effectively make the quality of the environment everyone's responsibility. No agency will then be able to maintain that it has no mandate or no requirement to consider the environmental consequences of its actions.*[25]

The need for a comprehensive environmental policy was never seriously disputed. It was recognized, however, that the mere declaration of a national environmental policy would not assure pursuit of its objectives.[26] Agencies could very well ignore a statement of policy if not compelled somehow to do otherwise. The concept of self-policing by federal agencies that pollute or license pollution was flatly rejected.[27] A mechanism to implement the policy was needed, an "'action-forcing' process that could be put into operation."[28]

Section 102(2)(C) of NEPA became the embodiment of the policy's "action-forcing" mechanism. The "detailed statement" prescribed in section 102(2)(C) would require "federal agencies, in submitting proposals, to contain within the proposals an evaluation of the effect of these proposals upon the state of the environment. . . ."[29] Similarly, "in the licensing procedures of the various agencies such as the Atomic Energy Commission or the Federal Power Commission or the Federal Aviation Agency there should also be, to the extent that there may not now exist fully or adequately, certain requirements with respect to environmental protection. . . ."[30] Still, many questions concerning the applicability, scope, and content of the "detailed statement" remained unanswered.

Analyzing federal actions in terms of their eventual effect on the status of the environment was thought to be a difficult undertaking, even for experts.[31] Expectations with respect to nonexpert agencies were not spelled out by Congress but necessarily derived from the two principal functions that the environmental impact assessment process was designed to serve: (1) to provoke thought in directions with which agencies were generally unfamiliar; and (2) to restore public confidence in the government's capacity to balance the total needs of society in its decisionmaking apparatus. A consultant to the Senate Committee on Interior and Insular Affairs on the drafting of NEPA observed:

> *The impact statement was required to force the agencies to take the substantive provisions of the Act seriously, and to consider the environmental policy directives of the Congress in the formulation of agency plans and procedures. To the extent that agencies have built the criteria specified in section 101 into their assumptions and policies and have utilized the planning procedures indicated in section 102(2)(A) and (B), the impact statement need be no more than a summary of agency action. Acknowledging exceptions, it may be generalized that impact statements of great length and detail indicate programs or projects of dubious environmental merit.*[32]

NEPA In Practice

On January 1, 1970, NEPA was signed into law, and the enabling legislation of scores of federal agencies was thereby supplemented. In broad but unmistakable terms, NEPA declared that regard for environmental quality was a national priority. Combined with other important policies, the new law sought to promote attainment of "the national goal of a quality life in a quality environment for all Americans,"[33] a goal with which virtually no one would take issue.

Early Implementation

During the first few years, most agencies struggled to implement NEPA, and some struggled to avoid its mandates altogether.[34] While the Council on Environmental Quality, located in the Executive Office of the President, issued general guidelines dealing with the preparation of environmental impact statements (EISs),[35] questions relative to timing, scope, and content remained. A universal solution to the problem could not be devised, due to the diversity of federal programs and the different aspects of the environments they affected. The indecisiveness with which NEPA was being implemented was not surprising, given the narrow interests of most federal agencies.[36] In any event, in its infancy the statute appeared to be floundering, lacking a champion with the authority to enforce its mandates.[37]

Although Congress had not anticipated that the courts would have a major role in the implementation of NEPA,[38] the judiciary took an active interest in the law at a time when it otherwise could have been enfeebled. Three elements combined in the early 1970s to stimulate court involvement. First, the ability to obtain judicial review of federal agency actions was ex-

tended by the courts to embrace special interest organizations alleging, on their behalf or on behalf of their members, injury to aesthetic and environmental well-being.[39] Second, partially in response to liberalized rules relative to "standing" to obtain judicial review, environmental interest groups grew in numbers, membership, and influence.[40] Finally, the courts themselves were increasingly disposed to review administrative action that touched on fundamental personal interests in life, health, and liberty, interests that "always had a special claim to judicial protection in comparison with the economic interests at stake in a ratemaking or licensing proceeding."[41]

The judicial reviewability of federal agency actions under NEPA and the scope of such review was tested early and often. Although courts uniformly held that NEPA would not serve as the basis for an independent cause of action,[42] judicial review of administrative actions under NEPA, which contains no express prohibition to the contrary, was consistently found to be available. In the case of *Calvert Cliffs Coordinating Comm.* v. *AEC*,[43] the scope of review was related principally to section 102 of NEPA, which "mandates a particular sort of careful and informed decisionmaking process and creates judicially enforceable duties."[44] The court determined that the provisions of section 102, "designed to see that all federal agencies do in fact exercise the substantive discretion given them [in section 101 of the act,] . . . are not highly flexible. Indeed, they establish a strict standard of compliance."[45] While the court found that the provisions of section 102 "are not inherently flexible . . . and must be complied with to the fullest extent," it did not dispose of the question whether the scope of review should go beyond the issue of procedural compliance, observing only that "reviewing courts probably cannot reverse a substantive decision on its merits, under section 101, unless it be shown that the actual balance of costs and benefits that was struck was arbitrary or clearly gave insufficient weight to environmental values."[46]

In *Environmental Defense Fund* v. *Corps of Engineers*,[47] the question of whether NEPA provides a basis for review of agency decisions on substantive grounds was answered clearly in the affirmative. There, the court read the language of NEPA and its legislative history to require more than "environmental full disclosure."[48] The court determined that the "action-forcing" proce-

dural provisions of section 102(2) were not ends in themselves. Rather, their purpose "is *to 'insure that the policies enunciated in section 101 are implemented.'*"[49] "The unequivocal intent of NEPA," the court found, "is to require agencies to consider and give effect to the environmental goals set forth in the Act, not just to file detailed impact studies which will fill governmental archives."[50] The court concluded that, in view of agency obligations to carry out the substantive requirements of the act, "courts have an obligation to review substantive agency decisions on the merits . . . [which] should improve the quality of agency decisions and should make it more likely that the broad purposes of NEPA will be realized."[51]

While many circuits held the view that NEPA was intended to effect substantive changes in agency decisionmaking, an equal number found that NEPA imposes no duties on federal agencies other than the procedural requirements of section 102(2).[52] The substantive vs. procedural division of opinion concerning NEPA mandates continued through the late 1970s. Then, in 1978, the Supreme Court addressed the issue in *Vermont Yankee Nuclear Power Corp.* v. *Natural Resources Defense Council*.[53] In that case, the Court was called upon to decide issues relative to the exercise of administrative discretion by the Nuclear Regulatory Commission in the context of several statutes, including NEPA. In a wide-ranging opinion delineating the bounds of judicial review of agency action, the Court observed that, as applied to decisionmaking undertaken pursuant to an agency's fundamental charter, NEPA "has altered slightly the statutory balance. . . ."[54] The Court went on to recognize that "NEPA does set forth substantive goals for the Nation," but found that "its mandate to the agencies is essentially procedural. . . . It is to insure a fully informed and well-considered decision, not necessarily a decision the judges of the Court of Appeals or of this Court would have reached had they been members of the decisionmaking unit of the agency."[55]

Any lingering doubts concerning the scope of judicial review of agency action under NEPA were put to rest two years later in *Strycker's Bay Neighborhood Council* v. *Karlan*.[56] There, the Court held that in the case of "a decision subject to NEPA's procedural requirements, the only role for a court is to insure that the agency has considered the environmental consequences; it can-

not 'interject itself within the area of discretion of the executive as to the choice of the action to be taken.'"[57]

The decisions in *Vermont Yankee* and *Strycker's Bay* do not purport to diminish the importance of NEPA in securing the national goal of a quality life in a quality environment. On the contrary, those decisions reinforce the clear intent of NEPA that environmental quality is an integral part of every agency's mission and must be considered along with other national policy objectives. And, as the Supreme Court has acknowledged recently, application of the essentially procedural requirements of NEPA are almost certain to affect agencies' substantive decisionmaking.[58]

The year 1978 marked the beginning of the end of inconsistent government-wide compliance with NEPA. In that year, the Council issued "regulations" for implementing procedural provisions. Although the Council's "guidelines," issued initially on April 30, 1970, and revised subsequently,[59] served to fill "the vacuum of uncertainties"[60] as to what might be required by NEPA, they "included only limited language to assist the agencies in developing separate procedures for . . . impact statements."[61] The EIS process also was being shaped by the courts, which were not reluctant to get involved in determining the adequacy of environmental processes undertaken by federal agencies. Courts also tended to measure agency compliance with NEPA against their own perception of the environmental values at stake. All of this had the effect of confusing, instead of clarifying, issues, with the result that "[r]ather than short, helpful analyses of probable impacts and options, environmental impact statements became mammoth discourses on every conceivable environmental effect and the butt of jokes about regulation and red tape."[62]

It was time to get back to basics.

Executive Order No. 11991 of May 24, 1977,[63] was promulgated to eliminate confusion caused by inconsistent implementation of NEPA. The Council was directed to issue regulations designed "to make the EIS process more useful to decisionmakers and the public; and to reduce paperwork and the accumulation of extraneous background data . . . to focus on real environmental issues and alternatives."[64] Other problem areas that had developed in implementing NEPA also were targeted,

including the need for concise and clear EISs as well as their early preparation in the decisionmaking process.

The regulations[65] promulgated under Executive Order No. 11991, with one minor change,[66] remain in force today, almost 12 years later. Durable and comprehensive, the Council's regulations have had the desired effect of standardizing basic NEPA compliance practices throughout the federal government. At the same time, through mechanisms such as scoping,[67] classification of actions,[68] incorporation by reference,[69] tiering,[70] and other procedures, the Council's regulations have been instrumental in keeping the NEPA process focused and useful to both decisionmakers and the public alike, while providing agencies substantial discretion to adapt those procedures to their programs.

Federal Decisionmaking

Despite the litigation that has shaped its history, the basic NEPA message remains unchanged after 20 years. NEPA tells all federal agencies to take the following steps:

- Think about the environment when planning any major action.
- Closely examine the need for and objective of projects, especially resource-intensive projects.
- Diligently search for alternatives that will not degrade the environment.
- Evaluate anticipated environmental effects to the extent necessary to delineate choices to decisionmakers and the public.
- Keep the federal decisionmaking process open, honest, and cooperative.

In the final analysis, the effectiveness of NEPA will be judged by the extent to which the nation puts its environmental ethic into practice. One way to measure that is to examine past

federal agency decisions and assess how those decisions were shaped by the NEPA process. The examples of federal actions that are described here demonstrate that federal agencies (and perhaps the nation as a whole) indeed have made progress in institutionalizing the NEPA ethic.

USDA/Forest Service: Vegetation Management[71]

Cooperation between the government and citizens affected by its actions is the foundation of a new vegetation management program that has been developed by the Pacific Northwest Region (Oregon and Washington) of the U.S. Department of Agriculture's Forest Service. The spirit in which all parties approached vegetation management in the Pacific Northwest has not always been cooperative. On the contrary, until fairly recently it was confrontational.

The Beginnings: Litigation

On July 13, 1983, a suit was filed in United States District Court for the District of Oregon by Northwest Coalition for Alternatives to Pesticides (NCAP), Oregon Environmental Council, and Audubon Society of Portland against the USDA/Forest Service and others. A judgement entered March 14, 1984, found that, "[t]he defendants have not prepared an adequate Worst Case Analysis, pursuant to their NEPA obligations. . . ." An injunction against the use of herbicides on defendants' lands was issued, and it was to remain effective until agency obligations were fulfilled.

The court order and injunction prompted the Forest Service to review its programs and policies to discover what had gone wrong. After considerable introspection, the Forest Service concluded that the legal action had been driven primarily by strong public reaction to the use of herbicides, a situation that had been allowed to degenerate to the point that all sides to the issue stopped communicating. Further, the Forest Service determined

that many of its employees, supervisors and nonsupervisors alike, shared the public's concerns. Despite those concerns, most people were not insisting on completely halting Forest Service herbicide spraying; instead they wanted their views to be included in program development. What the Forest Service program seemed to be lacking was a forum—other than the courthouse—in which to exchange viewpoints, ideas, and information.

The Parties

After studying the problem, the Forest Service concluded that the herbicide controversy transcended what chemicals were used, how they were used, and where. Rather, the public was concerned because the Forest Service did not seem to be adequately considering alternative methods of vegetation management or the full consequences of relying on herbicides. Consequently, the Forest Service chose to reach out to members of the public to seek their counsel on how best to proceed.

While the Forest Service's response to the controversy was evolving, so was the understanding and organization of the environmental community. There was a growing recognition that what works in one situation may not work in another, and that decisions associated with vegetation management have far-reaching implications. The way the Forest Service manages vegetation, for instance, affects the long-term sustainabilities of national forests which, in turn, are linked to the long-term vigor of local economies.

As the complexity and interconnectedness of the issues became more apparent, all parties began to better understand the opposing points of view. Better communication was seen as preferable to ongoing litigation, especially since the issues associated with vegetation management were so complex. Thus, all parties agreed to use the framework provided by NEPA to develop an environmental impact statement that would help solve the problem.

A New EIS, A New Program

In reinitiating the EIS process, the Forest Service decided to evaluate and develop anew all of its programs for vegetation management. The agency would examine programs from the ground up, carefully reconsidering all assumptions and policies while working closely with the concerned public. As a result, during the injunction, the Forest Service learned more about the use of nonchemical alternatives to herbicides.

Environmental and business interests also approached the task with a new sense of purpose. The University of Oregon's Western Natural Resources Law Clinic, representing the plaintiffs, began working together with the Forest Service to find ways for the parties in the lawsuit to resolve their differences outside of the courtroom. Oregonians for Food and Shelter (OFS), an organization representing the business community that had intervened on the side of the defendants, also helped explore for commonly agreeable solutions.

Before the Forest Service issued a Notice of Intent to develop a new vegetation management EIS, the key players met at the invitation of the Forest Service to establish common principles and agreements on how best to include the public in Forest Service decisionmaking. Those meetings were successful because all participants were willing to listen—and be receptive—to the other points of view.

During the course of the initial meetings, a variety of means for involving the public in Forest Service decisionmaking were worked out, including the following actions:

- Periodic mailings of progress reports,
- Issues workshops hosted by NCAP and OFS,
- Environmental and business community assistance to the Forest Service interdisciplinary team,
- NCAP and OFS leadership in coordinating involvement of the interests they represent,
- A special outreach program to Forest Service employees,
- Close coordination with other organizations, such as the Society of American Foresters.

An interdisciplinary team was formed by the Forest Service to develop the new vegetation management program. The team was responsible for collecting data, developing alternatives, estimating effects, evaluating alternatives, and recommending a preferred alternative. The team also helped refine issues to be considered in development of the new program.

The issues derived from meetings, workshops, and responses to the initial Request for Participation were used by the Forest Service interdisciplinary team to formulate the study's preliminary alternatives. A summary of the issues and preliminary alternatives was sent out to the public as Request for Participation No. 2. Based on the comments received, the alternatives were modified and a sharpened understanding of the issues was communicated to the public in Request for Participation No. 3.

The working groups put together by NCAP and OFS helped the interdisciplinary team understand and respond to the issues. In particular, both groups made significant contributions in helping the team define the kinds of alternatives to be considered, the human health risks associated with various approaches to vegetation management, and other analytical needs.

A draft EIS, on which public comment was invited, was issued by the Forest Service early in the summer of 1988. In November 1988, the Forest Service issued a final EIS that (1) recognized the variety of complex problems associated with herbicide use; (2) adopted site-specific management techniques to prevent the majority of vegetative problems, opting to handle nonchemically most of the problems that could not be prevented; (3) eliminated altogether the use of some herbicides of excessive or totally unknown risk; and (4) designated as a product of last resort one particular herbicide, 2,4-D.

After further negotiations, the NEPA process was finally concluded. The Forest Service now is resuming a balanced vegetation management program that includes selective, monitored application of herbicides. Moreover, the Forest Service currently is developing handbooks for implementation of the EIS, training Forest Service personnel in proper implementation procedures, and continuing communications with NCAP and the public.

Environmental Protection Agency: Protecting Water Quality

The Environmental Protection Agency (EPA) carries out environmental reviews under the National Environmental Policy Act for some of its activities, although it is exempted from NEPA for most of its regulatory programs. EPA conducts the majority of its NEPA evaluations on municipal wastewater treatment construction grant projects, new source water discharge permits, research and development projects, and ocean disposal site designations.

In 1980 EPA published a report entitled "Evaluation of EPA's EIS Program for Wastewater Treatment Facilities," which presented the results of an EPA study on EISs related to EPA-funded wastewater treatment facilities. This study, the first undertaken to determine the effects of NEPA on an agency program, examined 58 EISs prepared in the 10 EPA regional offices. It found that EIS preparation was effective in (1) causing major changes in projects, (2) providing more protection for the environment, (3) improving opportunities for public participation in the decisionmaking process, and (4) providing cost-savings that were the result of project changes prompted by the EIS process. Tables 2-1, 2-2, and 2-3 show some of the study findings. More recently, EPA has carried out further studies of projects and of benefits derived from the NEPA process. The results reinforce many of the findings of the 1980 study. The projects examined include wastewater treatment construction grants as well as other actions.

Overview of the Construction Grants Program

Most of the EISs that EPA has prepared are related to the grants it provides for the construction of wastewater treatment facilities. EPA currently provides up to 55 percent of the funding for municipalities to build treatment facilities necessary to meet water quality goals. The types of projects that are eligible for funding include wastewater treatment plants, interceptor sewers, and collector sewers.

Table 2-1.—Environmental Impact Statements (EISs) Causing Major Project Changes, by Category, 1980.

CATEGORY OF CHANGE	EISs CAUSING CHANGE	
	NUMBER	PERCENT
Location of Facilities	32	55.2
Capacity of Facilities	31	53.4
Areas to be Serviced	30	51.7
Level of Treatment	13	22.4
Method of Effluent Disposal	13	22.4
Land Use Priority	11	19.0
Sludge Disposal Method	9	15.5
Type of Treatment	8	13.8
Hook-up Controls	5	8.6

Table 2-2.—EISs Resulting in Environmental Benefits, by Category, 1980.

CATEGORY OF BENEFIT	EISs RESULTING IN BENEFIT	
	NUMBER	PERCENT
Surface Water Quality	41	70.7
Control of Induced Development	32	55.2
Floodplains	16	27.6
Wetlands	14	24.1
Archaeological Sites	14	24.1
Open Space and Recreational Lands	14	24.1
Aquifer Recharge (groundwater)	13	22.4
Prime Agricultural Lands	12	20.7
Historic Sites	12	20.7
Air Quality	8	13.8
Endangered Species (habitat)	5	8.6
Wild and Scenic Rivers	1	1.7

Table 2-3.—EISs Involving Public Participation, by Category, 1980.

CATEGORY OF PUBLIC PARTICIPATION	EISs INVOLVING PUBLIC PARTICIPATION	
	NUMBER	PERCENT
Public Meetings	55	94.8
Public Hearings	52	89.7
Special Mailings	33	56.9
Media Supplements	20	34.5

Note: Tabular material is based on an EPA analysis of 58 EISs made in 1980.
Source: EPA Office of Environmental Review, *Evaluation of EPA's EIS Program for Wastewater Treatment Facilities*, EPA, Washington, DC (November 1980).

The Clean Water Act allows states to administer certain elements of the EPA construction grants program under a delegation agreement. As part of that agreement, states are responsible for conducting the preliminary environmental studies that EPA uses in the preparation of environmental assessments (EAs) and environmental impact statements (EISs).

NEPA Benefits to the Construction Grants Program

The early application of NEPA to major projects and operations subject to EPA oversight not only promoted environmentally sensitive decisions but also contributed to more efficient planning and cost-effective implementation techniques.

Wastewater Treatment Facilities, Everett, Washington

In 1982 the city of Everett, Washington, began to define alternatives for expanding its wastewater treatment facilities on Smith Island in the lower Snohomish River Basin. The city's preferred alternative consisted of expanding the existing diked lagoon system into a wetland and disposing of sludge on site. In conjunction with an anticipated construction grant request under Title II of the Clean Water Act and a dredge and fill permit request under section 404 of the Act, EPA Region X and the U.S. Army Corps of Engineers, Seattle District, required the city to reevaluate alternatives so that both agencies could begin preparation of NEPA compliance documents. The Washington Department of Ecology also required further evaluation of alternatives pursuant to the State Environmental Policy Act.

Three environmental issues were of principal concern: the effects of inundating and diking 75 acres of wetland located in a 100-year floodplain near a major river that supports anadromous fisheries, the potential impact of sludge disposal within such an area, and recurring violations at the existing plant of water discharge permit conditions. In addition, the project required coastal zone consistency approval. The grant request and Corps permit decision required extensive negotiations and consultation among several agencies: EPA, the Corps of Engineers, the city management agency, and state agencies such as the Department of Wildlife and Ecology. Throughout the process several public meetings were held, with extensive public input.

The consultation process resulted in substantial changes in the city's plan. A new treatment and disposal alternative was selected that would impact only 11.2 acres (including 7.4 acres of wetland) and allow for an improved operating system with

higher capacity. The facility was redesigned to be in full compliance with federal flood insurance regulations and a new method of sludge disposal (composting with subsequent land application on silvicultural or agricultural areas off site) was selected.

The new plan had far less environmental impact, it met water-discharge permit conditions, and the public found it far more acceptable. Further, the 7.4-acre wetland impact was to be mitigated by reclamation and enhancement of a 13.3-acre disturbed wetland in the project vicinity, which satisfied resource agency concerns.

The resolution of these issues allowed both EPA and the Corps of Engineers to complete environmental assessments and determine that the final project would not result in significant impact to the human environment. Subsequently, EPA issued a Finding of No Significant Impact (FONSI); a construction grant was provided to the City of Everett in September 1988. The Corps of Engineers had issued a 404 permit to the city in December 1987. When the project is completed, Everett, Washington, will have obtained a reliable treatment facility with higher capacity and fewer environmental impacts than were proposed in 1982, and at a lower cost to its citizens.

Wastewater Treatment Facilities, North Carolina Barrier Islands

In 1982 the EPA Region IV office was concerned with the impact of federally financed development on the North Carolina barrier islands. EPA had received six plans for wastewater treatment facilities on the barrier islands; five of those plans proposed regional treatment systems to replace existing local treatment works.

Region IV had three major concerns about these plans:

- Would the increase in treatment capacity stimulate substantial new growth?
- What would be the impact of this growth on sensitive island environments such as dunes and wetlands?
- Would the local communities have the financial capability for plant construction and operation?

As a result of its concerns, EPA decided to prepare an EIS on wastewater treatment for the North Carolina barrier islands. The draft EIS was issued in June 1983; following public review and comment, a final EIS was issued in January 1984. The EIS looked at options for wastewater treatment ranging from continued use of existing facilities to construction of the regional treatment plants originally proposed.

The EIS also examined water quality problems related to wastewater treatment and development. An especially important finding was that the impact of septic tank discharge on shellfish bed closure had been overestimated, and that nonpoint runoff resulting from development was a larger factor in such closures than had been thought. The adverse impact of development on groundwater also was assessed.

The EIS found that development resulting from regional treatment systems could well have adverse environmental impacts that would diminish the benefit to water quality from additional waste treatment. As a solution to this problem, the EIS identified a strategy for barrier island communities to more precisely determine wastewater treatment needs and to balance those needs against environmental impacts and financial considerations.

NEPA Reviews of Projects Involving New Source Water Discharge Permits

Under section 306, section 402, and section 511 (c) (1) of the Clean Water Act, EPA authorizes permits for the discharge of effluent into U.S. waters. Where issuance of permits has not been assumed by a state, EPA is required to comply with NEPA in issuing new source permits for discharges subject to new source effluent guidelines. EPA has this responsibility in 13 states and on Indian reservations.

In Oklahoma, New Mexico, and Arkansas, most NEPA review activity by EPA for water discharge permits has been related to coal mining operations. Many such operations tended to pull out of their projects before proper reclamation was completed. In New Mexico, for example, operators claimed that they were no-discharge operations and therefore required no permits.

In Arkansas, some operations were able to proceed unrestricted because they were claimed to be exploration projects.

In a coordinated effort, EPA, the Department of the Interior's Office of Surface Mining, Reclamation, and Enforcement (OSM), and state agencies began working together to enforce NEPA and stop the improper permitting and operation of such coal mines. EPA and OSM developed an agreement to incorporate each other's permitting procedures to ensure compliance with the pertinent regulations and expedite the permitting process. New Mexico's Environmental Improvement Division and Energy and Mineral Mining Agency were able to more vigorously enforce their regulations and monitor operations. This cooperative effort led to eight environmental reviews and five cancelled permit applications.

In Oklahoma, irresponsible operators were entering sensitive and impacted areas and leaving open pits, overburden, and gob piles unreclaimed. By enforcing the NEPA review process on the water discharge permits and requiring proof of executable reclamation bonds, EPA and the state of Oklahoma were able to eliminate some of these types of practices in environmentally sensitive areas.

In Arkansas, NEPA reviews by EPA resulted in operators being more responsive to environmental issues. Potential impacts on cultural resources and mitigation measures received greater attention and significance.

Red Dog Mine Project

In 1983 the EPA Region X office prepared an EIS in connection with a water discharge permit application for a lead/zinc mine on native lands in northwest Alaska. Two environmental issues were of principal concern: the effect of a 57-mile access road on the Cape Krusenstern National Monument and the potentially toxic impacts on the Wulik River, which is used by Alaskan natives for subsistence fishing. In addition, the permit decision required extensive negotiation and consultation with the state, Alaskan natives, and the Department of the Interior. Also, Presidential and Congressional approval was needed for any development in the national monument area.

The final EIS was issued jointly by EPA and the Department of the Interior (DOI) in September 1984. The EIS analysis resulted in an approach to siting and operation of the mine that would actually reduce zinc contamination of waters from naturally occurring levels. As part of the EIS, EPA and DOI assessed alternative access routes. As a result, both agencies determined that the route through the national monument was actually the alternative with the least environmental impact. The EIS addressed environmentalists' concerns and provided a good basis for obtaining Presidential and Congressional approval of this option.

Department of Defense: The Fort Polk Story

In December 1983 the U.S. Army decided to equip the 5th Mechanized Infantry Division at Fort Polk, Louisiana, with the newest combat vehicles—the Abrams main battle tank, the Bradley fighting vehicle, and the Apache attack helicopter. The Directorate of Engineering and Housing (DEH) at Fort Polk foresaw the need to build a modern test range and training facilities for the new vehicles. The DEH planners therefore began working on a new Multi-Purpose Range Complex (MPRC) to support the infantry, armor, and helicopter training requirements.

The personnel at Fort Polk made environmental considerations an integral part of the planning process. Their approach and the resulting environmental impact statement are good examples of how both mission and environmental objectives can be met simultaneously.

Initially, the planners identified three sites within the boundaries of Fort Polk that would meet training requirements. The Fort Polk command group selected Site 2 as the preferred alternative based on the mission requirements for multiple engagements, intervisibility of target, course length, and unit combination. DEH planners then set about evaluating the construction feasibility and potential environmental impacts for that site.

Past environmental surveys had discovered an endangered species—the red-cockaded woodpecker—nesting in trees within Site 2. Consequently, the DEH planners selected another site for evaluation. They conducted a mission analysis and prepared an Environmental Assessment (EA) for both sites. The mission analysis showed that Site 2A was the new preferred alternative, because it could provide more realistic training. However, the EA found that Site 2A would cause more severe environmental impacts than Site 2. The planners at Fort Polk then decided to prepare an EIS encompassing all four sites.

Because of time constraints and lack of funds, the DEH decided to do the EIS "in-house." Fort Polk's ecologist was assigned the duty of directing the EIS effort. The nine-person DEH environmental division had expertise in acoustical engineering, biology, and chemistry. Moreover, since about half of the Fort Polk military reservation is permitted from the USDA/Forest Service, a full-time f orestry liaison officer was available to support the EIS effort. The environmental division supplemented their in-house expertise by contracting for assistance with archaeological, groundwater, noise-modeling, and woodpecker studies.

The in-house interdisciplinary approach to environmental analysis had several advantages over contracting for all environmental services. First, it allowed the necessary documentation to be prepared much more quickly. Second, it reduced the cost far below what an outside consultant would have charged. Finally, the predominantly in-house effort produced a product with appropriate focus. It also enabled the personnel who would be monitoring the project to understand its potential impacts. The key to the real success of the EIS process, however, was early incorporation of environmental analysis into the planning process, an action that facilitated a spirit of cooperation which, with encouragement from the military leadership, led to the EIS being an integral part of mission planning and decisionmaking.

Prior to the EIS effort, the EA had addressed most of the major environmental issues and had identified those likely to cause public controversy. The Fort Polk planners had expected strong opposition from environmentalists and the public over the threat to the endangered species and the reduction of hunting areas. Surprisingly, however, the issue that generated the most concern at a well-attended scoping meeting was noise.

Fort Polk's managers decided to hold a public hearing in the evening and at a location convenient to the public. A panel consisting of representatives from all involved and affected units within Fort Polk were present to answer questions raised by the public. Because the military leadership was cooperative and concerned, the resulting discussion was friendly and productive. An EIS framework was laid out to address all expressed concerns, including a thorough analysis of potential noise impacts.

The ensuing environmental study disclosed the following factors:

- Site 2A had more red-cockaded woodpecker nests than any other site considered.
- The area's slopes and streambanks were extremely erodible and would require erosion control measures to avoid long-term environmental impacts.
- The local community was strongly opposed to Site 2A because of noise. Although the community was not opposed to the testing, it would likely solicit local officials to block it if Site 2A were selected.

The EIS process led to the following conclusions:

- Site 1 rated poorly on both mission criteria and environmental impacts.
- Site 2 rated satisfactory on both mission criteria and environmental impacts.
- Site 2A was the best alternative on the basis of mission criteria but would have adverse environmental impacts.
- Site 3 rated poorly on mission criteria but was the best alternative on the basis of environmental impacts.

The Fort Polk commander selected Site 2 for the Multi-Purpose Range Complex. The public and environmental groups accepted the analysis, because environment-enhancing mitigation measures had been identified to help protect natural resources. Mitigation included protection of the red-cockaded woodpeckers' nests, soil erosion control, forest management changes, and wildlife protection.

Construction of the MPRC was managed by the Army Corps of Engineers, Fort Worth District, which awarded a contract after a predesign conference and design reviews attended by Fort Polk environmental managers. The MPRC was designed to avoid the red-cockaded woodpeckers' habitat, archaeological sites, and erosion-prone areas. The design also enhanced the realism of the training by maintaining the natural barriers that combat troops might encounter.

However, since the Corps underestimated the environmental sensitivity of the site, many of the environmental mitigation measures were not properly implemented. Such measures included small downstream sediment basins, diversion berms, sodded ditches, interceptor berms, and grade stabilization structures. In particular, the Corps did not require the contractor to install sediment basins prior to site clearing as specified in the EIS.

Fort Polk environmental specialists were monitoring the Corps and its construction contractors to ensure implementation of the mitigation measures identified in the EIS. The environmental specialists insisted that the Corps issue a contract change order to better implement the erosion control measures. The change order was issued. Fort Polk had learned that identifying mitigating actions in the EIS is not enough. The actions must be adopted, incorporated, and monitored by the construction agent.

The National Environmental Policy Act is intended to incorporate environmental impact considerations into mission planning and decisionmaking. This goal was clearly achieved at Fort Polk. The EIS influenced the site selected for the MPRC and identified mitigating measures to reduce adverse environmental impacts. All this was accomplished without slowing down the project and at very little cost. Fort Polk was able to successfully balance the need for modernized Army training with the need to protect the environment by effectively managing and using the NEPA process.

Influence on State and Municipal Governments

The National Environmental Policy Act recognizes that the participation of state and local governments is essential to achieve the goal of a high quality environment for all citizens, and the act encourages cooperation among all levels of government.[72] While NEPA was intended primarily to shape federal decisionmaking, its sponsors were confident that "State, local, and private action [would] also be favorably influenced."[73] The sponsors of NEPA also believed that it would "provide a model and a demonstration to which state governments may look in their efforts to reorganize local institutions and to establish local policies conducive to sound environmental management."[74] The value of NEPA as a model for state governments grew out of the belief that "many of the most serious environmental problems. . . [were] within the scope and, often, within exclusive jurisdiction of state action and state responsibility."[75]

As expected, a number of states implemented a system of environmental impact assessment, modeled after NEPA, in the early and mid-1970s. Frequently referred to as "little NEPAs," these laws vary a great deal in respect to their legal basis, administration, and requirements. Nineteen states, the District of Columbia, and Puerto Rico have enacted "little NEPAs" by statute or executive order.[76]

Some states, such as California, New York, and Washington, have established vigorous environmental impact assessment (EIA) systems, supported by comprehensive regulations and active judicial enforcement.[77] In states with such systems, state courts often cite federal case law as guidance. Other states have systems that apply to a narrower range of activities[78] and that appear to be less dynamic in their relationship to state decisionmaking.

Recently, there appears to be a resurgence of interest in state "little NEPAs." In 1986 the Montana Environmental Quality Council held a conference focusing on Montana's EIA process. In November 1987 CEQ cosponsored with the Environmental

Law Section of the New York State Bar Association a conference focusing on the preparation and review of environmental impact statements at both the state and federal levels. The State of Washington undertook a major revision of its State Environmental Protection Act in 1988, and in 1989 the Council of the District of Columbia passed its first "little NEPA" law.

Also in 1989 the governor of New Jersey revised the Executive Order governing the New Jersey environmental impact assessment process. Meanwhile, recent California case law[79] has confirmed the continuing viability of the California Environmental Quality Act, long viewed as a model for other states. This year, the states of Michigan and Maine are considering the establishment of state agencies, similar to CEQ, that will be responsible for the states' environmental impact assessment process.

Several municipalities also have adopted "little NEPA" procedures. For example, New York City established an EIA procedure by Executive Order in 1977 as part of its responsibilities under New York's State Environmental Quality Act.[80]

A Model for Other Nations

The analytical process established by NEPA, known internationally as environmental impact assessment (EIA), is a model for comparable systems worldwide. While most EIA systems that are in place today can trace their origins to NEPA, many systems have not incorporated all of its structural and procedural features. The components of NEPA, or any EIA system, include a formalized legal framework and the linking of EIA to the decisionmaking process.[81] However, one particular feature, external review of the environmental process,[82] is a vital part of the NEPA process in this country, and it appears to be critical to the viability of EIA internationally.

Sovereign States

Following the passage of NEPA in 1969, several other nations established EIA systems, either through specific legislation as in Colombia, France, and Thailand,[83] or through Executive or Cabinet decrees as in Canada and the Netherlands.[84] The lack of a formalized legal framework in some countries allowed the EIA system to be eroded when government agencies refused to cooperate.[85] Other systems experienced problems when the government decisionmaker failed to actively consider the EIA. Observers of EIA in both Latin America[86] and Asia[87] point out that EIA often has been applied too late in the planning process to be effective, and that an earlier incorporation of EIA is necessary.

Certain EIA systems that did set up external review processes were effective, in spite of their lack of legal structure. In both the Netherlands and Canada, independent review panels issue guidelines for the preparation of EIA documents and review them once they have been prepared.[88] In the Netherlands, the competent authority must prepare a special report explaining the decision and presenting the conclusions drawn from the EIA.[89] While the early EIA systems of Canada and the Netherlands differed from the NEPA process in terms of openness and opportunities for public participation, the provisions for external review served to expose the environmental process of each country to a measure of scrutiny. Such external review has been credited for the durability and overall effectiveness of both systems.

In the 1980s EIA systems without external review mechanisms tended generally to falter. In Colombia and Thailand, EIA systems were established by specific legislative enactments without adequate provisions for external review. For example, under section 18 of Thailand's Improvement and Conservation of National Environmental Quality Act of 1975, a project proponent or licensing agency must consult with the National Environmental Board, but may actually begin projects or licensing activities before the EIA process is completed. Furthermore, EIA documentation is not released to the public, and interested persons have no way of knowing whether or not the EIA process for a given project has even been undertaken.

In Colombia, sections 27 and 28 of the Code of Renewable Natural Resources and Protection of Environment call for preparation of EIA documents for any activity likely to produce environmental damage. But because project or impact criteria that would trigger preparation of EIA documentation are not entirely clear, and clarification by means of external review is generally unavailable, the environmental effects of most public projects are not evaluated.[90]

Without external review, environmental planning by government agencies can be subject to possible abuse and mismanagement, especially in times of social and economic disorder. External review can contribute to the effectiveness and integrity of EIA processes in many countries where government agency oversight is currently sparse and few opportunities exist for public participation in decisionmaking.

External review has contributed not only to the widely acclaimed effectiveness of the EIA systems in both Canada and the Netherlands, but also to the subsequent improvement of those systems. Canada, for example, codified its EIA system in 1979 and subsequently promulgated specific EIA guidelines that include provision for a much more open review process.[91] Under sections 20-32 of Canada's EIA guidelines, an independent panel is now appointed by the Minister of Environment to follow the EIA process and to review documentation for adequacy.[92] Perhaps more importantly, the general public is given access to all the panel's information during the course of review. The Netherlands codified its EIA system in 1986, strengthening both public review and the supervisory role of the EIA Commission.[93]

International Organizations

In recent years, many nongovernmental and international organizations have shown an interest in developing methods to integrate environmental review and economic planning. In 1985, for example, the Council for the European Community (EC) issued a directive establishing an EIA procedure to harmonize existing legal provisions in member states.[94] The directive establishes minimum EIA requirements regarding the type of

projects that would be assessed, the principal obligations imposed on project proponents, and the contents of assessments. With respect to the issue of external review, article 6.2 of the EC directive requires that "[m]ember states shall ensure that . . . the public is given the opportunity to express an opinion before the project in initiated."

Many observers have criticized the EC initiative for simply formalizing those basic provisions for project assessment that already exist in most member states.[95] Further, the EC directive does not require the EIA process for program or policy initiatives, but instead recognizes the more popular "category" system that allows member states to limit the application of EIA to a small group of selected projects. The fact that an international organization has emphasized the EIA process, however, and has specifically required public participation certainly raises the profile of the process and may have a positive effect on environmental law and policy in member states. Indeed many EC countries that do not now have an EIA process are in the process of drafting legislation that would establish an EIA process going far beyond the EC directive and, perhaps, NEPA.[96]

Other international organizations have made recommendations to their member states relative to establishment of EIA procedures. Among those, the Organization for Economic Cooperation and Development (OECD), the U.N. Environment Program (UNEP), and the Antarctic Treaty Consultative Parties have all established guidelines for EIAs that are more complete and far-reaching than those in the EC directive.[97]

The organizations, however, with the greatest potential today to influence international EIA are the multilateral development banks, such as the World Bank. In 1989 the World Bank issued its Operative Directive, which provides that an environmental assessment is "normally" required for certain categories of projects.[98] The procedures set out in the Directive do not mandate that the borrower must submit an EIA document, but only require that "[t]he borrower should submit the final EA report to the Bank prior to Bank appraisal [of the project]."[99] The World Bank has stated that it is the borrower country's responsibility to prepare the document, and that the bank will supervise the process.[100] Certainly, the countries planning and carrying out development programs should be incor-

porating EIAs into their own planning procedures. However, the Directive appears to lack the formality and mandatory nature that would compel borrower countries to adopt EIA procedures.

In many respects, World Bank procedures, like the EC Directive, are not as comprehensive as those promulgated by UNEP. For example, the World Bank Directive does not expressly apply to sectoral and structural adjustment programs, often the Bank's most important activities. Nor do those procedures set out specific requirements for external review, so needed in borrower countries.[101] Still, the EC and World Bank directives represent first steps toward establishing effective, efficient EIA processes to help reconcile economic growth and development with maintenance and enhancement of environmental quality on a global scale.

Notes and References

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74. Senate Rep. No. 91-296, page 8.

75. Senate Rep. No. 91-296, page 8.

76. Ark. Stat. Ann. sec. 8-1-101; Cal. Pub. Res. Code sec. 21000 *et seq.*; Conn. Gen. Stat. Ann. sec. 22a-14 to 22a-20; District of Columbia Environmental Policy Act of 1989; Bill 8-8; Fla. Stat. sec. 380.92 *et seq.*; Hawaii Rev. Stat. sec. 343-1-343-8; Ind. Code Ann. sec. 13-1-10-1-10-8; Md. Nat. Res. Code Ann. sec. 1-301 to 305; Mass. Ann. Laws ch. 30, sec. 61-62H; Executive Order 1974-4 (Michigan); Minn. Stat. Ann. sec. 116D.01 to 07; Mont. Code Ann. sec. 75-1-101 to 75-1-105; 75-1-202; Executive Order 215 (September 11, 1989) (New Jersey); N.Y. Environ. Conserv. Law sec. 8-0117; N.C. Gen. Stat. sec. 113-A-1 to 10; P.R. Laws Ann. tit. 12, sec. 1121-1127; S.D. Codified Laws Ann. sec. 34A-9 to 34A-9-12; Va. Code 10-17.107 to 10-17.112; State of Utah Executive Order (August 27, 1974); Wash. Rev. Code sec. 43.21C010-21C.910; Wash. Admin Code R. 197-11; Wis. Stat. sec. 1.11 and Wis. Admin. Code NR 150.01-40.

77. See, Mandelker, D.R., *NEPA Law and Litigation*, Callaghan & Company, Deerfield, IL (1984, 1988 Supp.), Chapter 12. The author discusses the "little NEPA" laws of California, New York, and Washington, and gives an overview of state "little NEPA" laws in general.

78. Virginia's law, for example, is triggered only by state projects costing $100,000 or more, except for road and highway projects.

79. See, for example, *Laurel Heights Improvement Assn.* v. *Regents*, 47 Ca. 3d 376 (1988).

80. New York City Executive Order No. 91, June 1977. The determination of "permanent" lead agencies in New York City's process was held to be unlawful in *In the Matter of the Coca-Cola Bottling Company of New York, Inc.* v. *The Board of Estimate of the City of New York*, (1988). The court held that the determination of the significance of environmental impacts of a proposed project must be made by the agency with principal responsibility for approving the project (just as in federal practice).

81. See generally Taylor, S., *Making Bureaucracies Think*, Stanford University, Stanford, CA, (1984); Kennedy, W., "Environmental impact assessment in North America, Western Europe: what has worked where, how, and why," *Int. Environ. Rep.* (BNA) (April 13, 1988), pages 257-262.

82. External review includes (1) review of the EIA process or documents by another government or independent agency, such as the review of Canadian EIA documents by the Environmental Assessment Panel, P.C. 1984-2132, June 21, 1984, *Canada Gazette*, Part II (November 7, 1984), 118(14):2794; (2) public participation, such as in the NEPA "scoping process," (40 C.F.R. 1501.7 [1978]) and public comment on documentation (40 C.F.R. 1502.9 [1978]); and (3) judicial review, such as the "Public Inquiry" system in the United Kingdom and France, see Wathern, P., ed., "The EIA directive of the European Com-

munity," pages 196, 199-200 in *Environmental Impact Assessment: Theory and Practice*, Unwin Hyman, London (1988).

83. Codigo Nacional de Recursos Naturales y Proteccion del Ambiente, §§ 28-29, Decreto 2811, 1974 (Colombia). Loi du 10 Juillet 1976 sur la protection de la nature (*J.O.* du 13 Juillet 1976 et rectificatif, *J.O.* du 28 Novembre 1976); Decret d'application no. 771141 du 12 Octobre 1977 (France). Improvement and Conservation of National Environmental Quality Act 17-19, 1975 (Thailand).

84. 1973 Cabinet Directive as described in Federal Environmental Review Office, *The Provisions of the Policy of the Government of Canada Establishing the Federal Environmental Assessment and Review Process*, (1979). Ministry of Health and Environmental Protection, *Governmental Standpoint on Environmental Impact Assessment*, The Netherlands (1979).

85. Abracosa, R., and L. Ortolano, "Environmental impact assessment in the Philippines: 1977-85, "*Environ. Impact Assessment*" (1988), 7:293; see generally, Moreira, I., "EIA in Latin America," page 239 in Wathern.

86. Moreira, "EIA in Latin America," pages 239, 247 in Wathern.

87. Htun, N., "The EIA Process in Asia and the Pacific Region," pages 225, 238 in Wathern.

88. Wathern, pages 192, 197; Canadian Environmental Advisory Council, *Preparing for the 1990's Environmental Assessment, an Integral Part of Decision Making*, Canadian Environmental Advisory Council, Ottawa (1988), page 17.

89. Coenen, R., and J. Jorissen, *Environmental Impact Assessment in the Member Countries of the European Community*, Federal Environmental Agency, Bonn, Germany (September 1989), page 39.

90. Moreira, pages 238, 245-247 in Wathern.

91. Government Organization Act, 1979, Section 6; P.C. 1984-2132, June 21, 1984, *Can. Gazette*, Part II, 118(14)SOR/84/467 (November 7, 1984).

92. Further revisions to the EIA process have been suggested by an independent advisory council. Canadian Environmental Advisory Council, page 17-18.

93. Environmental Protection (General Provisions) Act, *Bull. of Acts, Orders and Decrees*, No. 211, The Netherlands (1986).

94. Council of the European Communities, *On the Assessment of the Effects of Certain Public and Private Projects on the Environment, O.J.* Eur. Comm. (May 28, 1985), 28(L-175).

95. Wathern, page 207; see generally Coenen and Jorissen.

96. Coenen and Jorissen, page 18. The authors point out the proposed systems for Italy, Greece, Portugal, and Spain that actually go beyond NEPA in giving a role to the Environment Minister in approving development projects.

97. Organization for Economic Cooperation and Development, *Recommendations of the Council on Measures Required to Facilitate the Environmental Assessment of Development Assistance Projects and Programmes*, C(86)26, OECD, Paris, (1986); U.N. Environment Program, *Goals and Principles for Environmental Impact Assessment*, UNEP/GC.14/17, UNEP, Nairobi, (1987), Principle 7 states, "Before a decision is made on an activity, government agencies, members of the public, experts in relevant disciplines and interested groups should be allowed appropriate opportunity to comment on the EIA"; Antarctic Treaty Consultative Parties, "Man's impact on the environment: environmental im-

pact assessment," Recommendation XIV-2 in *Handbook of the Antarctic Treaty System*, ATCP, Rio de Janeiro (April 1989), page 2106.

98. World Bank Operational Directive 4.00, Annex A: *Environmental Assessment* (September 18, 1989). The Asian Development Bank has also established procedures in which certain projects are analyzed for their environmental factors. See generally, Asian Development Bank, *Environmental Planning and Management and the Project Cycle*, ADB, Manila (May 1988).

99. World Bank § 24.

100. World Bank § 16.

101. The lack of reliable technical information and effective enforcement of environmental laws in developing countries accentuates the strong necessity for public participation and review. See Mayda, J. "Environmental legislation in developing countries: some parameters and constraints," *Ecology Law Q.* 12:997 (1985).

September 5, 1984

On September 5, 1984, a helicopter landed on a lake in the Adirondack Mountains. A man and a woman with electronic equipment and sampling gear emerged from the helicopter, took measurements, and filled several bottles with water from the lake. The helicopter then flew to another lake in the Adirondacks where the scene was repeated.

On September 5, 1985, two hikers carrying similar equipment backpacked into the Wind River Wilderness Area of Wyoming. Those hikers also took measurements and water samples from several lakes in the area.

Both teams were part of a national effort to estimate the number of lakes that were acidic or potentially sensitive to acidic deposition in the eastern and western United States. Scientists from the Environmental Protection Agency sampled lakes and streams in the eastern United States; they worked jointly with scientists from the Forest Service to sample lakes in the mountainous West. The data collected by these teams became part of a landmark environmental study: the National Surface Water Survey. That study was significant because for the first time federal, state, and local agencies came together and coordinated their efforts to conduct a comprehensive assessment of a regionwide environmental problem.

CHAPTER 3

Environmental Data and Trends

Establishing the status and trends in environmental quality by collecting environmental data is essential for formulating, implementing, and maintaining a successful national environmental policy. Environmental status and trends data help define the health of ecosystems and identify the specific causes of environmental degradation. They help legislators to write effective environmental laws, and they assist regulators in implementing reasonable environmental regulations. And environmental status and trends data support the nation's efforts to determine whether its environmental laws and regulations are doing what they were intended to do.

One measure of this nation's progress in protecting the environment is the increased emphasis on environmental data collection now compared to 1970. Over the past 20 years, the United States has made significant progress in this area, and the nature of that progress suggests that environmental data will become even more important to national environmental protection efforts in the future.

Historical Perspective

Over the past two decades, advances in monitoring techniques have improved methods for collecting environmental data and defining environmental trends.

Environmental Data and Trends in the 1970s

Interagency studies like the National Surface Water Survey did not exist in 1970. Instead, environmental data were collected independently by local, state, and federal agencies to meet specific regulatory compliance needs. Environmental monitoring programs typically were not coordinated among agencies, because data collection objectives differed.

For example, some states with the authority to regulate municipal and industrial discharges into local rivers and streams under the Clean Water Act[1] would locate water quality monitoring stations above and below local discharges into streams. A state game and fish department or the federal Fish and Wildlife Service, whose mission is to protect fish and wildlife, would collect water-quality and aquatic-biology data along a gradient within the same stream to assess the health of the fish and benthic invertebrate communities. Yet the data often were not comparable, because they were collected at different locations, at different times of the day or year, using different collection methods, or with different quality assurance procedures. Thus the potential value of the data was much diminished.

In the 1970s environmental data typically were collected in response to, rather than in anticipation of, environmental prob-

lems. For example, monitoring the condition of local ecological resources often was initiated after problems became obvious to the local community (for instance, after accidental releases or spills of hazardous chemicals, extensive fish kills in local streams, or clearcutting). Other monitoring programs were established on a case-by-case basis to answer ongoing concerns about localized environmental problems, such as those within a specific stream segment. The collection of data generally was limited to a single environmental medium (such as water or land) and was intended to assess the impacts of specific chemicals (such as pesticides, oil, or toxics) or human activities (such as strip mining or highway construction) on a particular biological species. Because many of the monitoring programs were discontinued once the problems were corrected or protection measures implemented, the length of time over which the measurements were taken often was short and fragmented. Furthermore, it was not possible to determine if the problem was corrected once monitoring was discontinued.

The short-term, localized, single-agency, "responsive" approach to data collection in the 1970s left the nation with little useful information with which to assess the overall condition of the environment or to detect long-term trends in environmental quality. Further, those approaches were of little help in evaluating the effectiveness of long-term pollution control activities.

Water quality monitoring in the Great Lakes exemplifies how environmental monitoring in the 1970s sometimes limited the assessment of environmental quality and misjudged the causes of environmental decline. During the 1960s the discharge of sewage and other industrial wastes into Lake Erie reduced the levels of dissolved oxygen essential for the survival of fish, benthics, and phytoplankton. Decreased levels of dissolved oxygen were compounded by the proliferation of blue-green algae in the surface water, which created surface scums and taste and odor problems in the water. Further losses of key benthic and planktonic species—a food supply for many fish species—occurred. Populations of game fish dropped sharply because of the loss of their food supply and the introduction and proliferation of pest fish species such as the sea lamprey. The public began to voice concern over the "death" of Lake Erie.

Monitoring programs established by local and state agencies collected water samples from areas around the discharge pipes of industrial and wastewater facilities. Other agencies collected biological data from random locations within the lake. Water quality monitoring focused on the pollution effects from point sources (that is, discharges from individual municipal sewage treatment plants and industrial facilities) and missed important contributions from nonpoint source pollution, specifically from agricultural runoff high in nitrates and phosphates. It was not until data were collected from both point and nonpoint sources within the Lake Erie watershed in the late 1970s that ecosystem-wide or landscape approaches to pollution control began to be developed. (For a more complete discussion of historical changes in water quality in the Great Lakes, see Chapter 8 of this report.)

Changes in Environmental Monitoring

As the 1970s came to an end, the nation began to change its perception of the value of environmental data and the way such data should be collected. For example, in 1977 the National Research Council identified the lack of statistical rigor in the design and analysis of most environmental monitoring networks.[2] Coordination and cooperation among federal agencies were recommended to improve the accuracy and usefulness of environmental status and trends data. In 1980 the Council on Environmental Quality (CEQ) noted the extensive duplication of agency efforts and the lack of an agency with a national perspective.[3] CEQ recommended better interagency coordination and cooperation and improved quality assurance practices. And in 1981 the General Accounting Office identified the dichotomy between the information collected in most monitoring networks and the information required for decisionmaking.[4]

Those changing perceptions and the subsequent changes in monitoring programs have improved the nation's ability to as-

sess the condition of the environment and identify trends in environmental quality.

First, the nation became more aware that the quality of the environment cannot be described meaningfully using trend data related to a single species or a single environmental medium. Rather, the environment consists of complex interactions among multiple species and multiple media occurring over large geographical areas. For example, air pollution not only can cause the decline and death of particular species of trees within a forest ecosystem, but it also can affect a multitude of animal species that rely on those trees for food and shelter. Additionally, more subtle changes, such as an increase in temperature and moisture on the forest floor and rapid leaching of nutrients from the soil, could have far-reaching impacts on the stability and quality of the forest ecosystem.

Second, although the ecosystem concept had been understood for many years, it was not until the 1970s that ecosystems like lakes, streams, forests, wetlands, and oceans were recognized as the basic functional units of the environment. Thus, the critical need for environmental monitoring programs that would collect consistent, comparable, quality-assured data at the ecosystem level also was recognized.

This emphasis on the ecosystem as a whole was a driving force in the changes that took place in environmental monitoring during the 1980s. Ecosystems include both living organisms (plants, animals, microorganisms) and a nonliving environment (water, air, soil) that are inseparably interrelated and interactive. Furthermore, ecosystems do not exist or function in isolation; the range of ecosystem types found in the United States are closely interrelated. Changes occurring in one ecosystem result in changes in other ecosystems. For example, the widespread application of fertilizers, herbicides, and pesticides in agricultural ecosystems can alter water chemistry and biology in stream, river, and lake ecosystems hundreds of miles away. Therefore, an adequate assessment of the status and trends in environmental quality requires monitoring networks and data collection over multiple ecosystems and on a regional scale.

Because changes within ecosystems and the consequent effects on adjacent ecosystems can happen very slowly, they are often subtle and difficult to detect. For example, studies of the

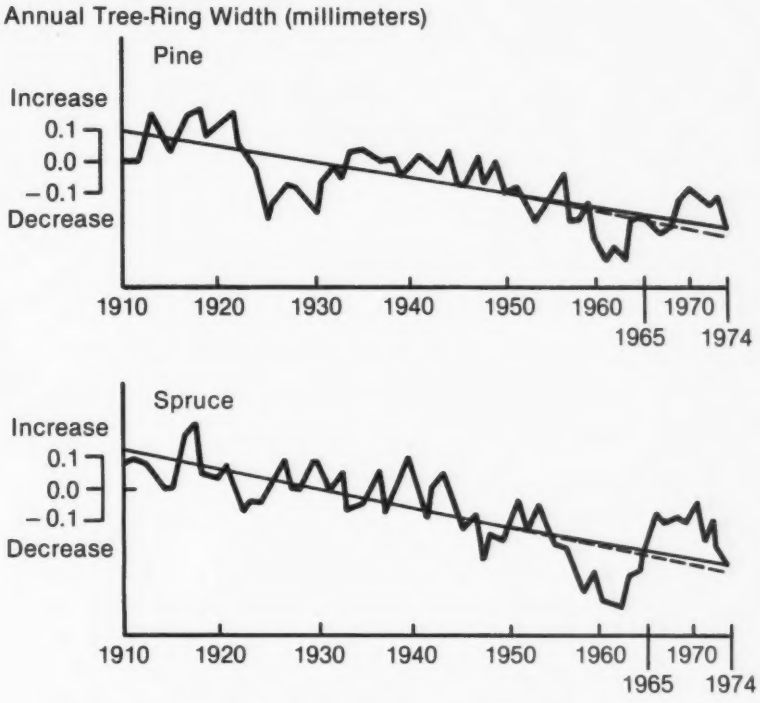
recovery of clearcut forests revealed that 20 years was perhaps 1/20 of the time needed by some forests to reach a mature condition.[5]

Detecting environmental trends that result from natural or man-induced ecosystem changes requires the continuous collection of a consistent set of environmental data over a long period of time—from years to decades. Although some human activities, such as clearcutting, channelization, or wetland drainage, have very obvious effects on ecosystems, long-term environmental monitoring is necessary to detect long-term trends that result from cumulative impacts. For example, toxic substances can accumulate in stream sediments, and salts can build up in soils because of continuous evaporation in irrigated agricultural fields.

While short-term data may be useful to describe short-term impacts, environmental trends revealed through monitoring programs of 2-5 years provide a very different picture of overall trends within an ecosystem than monitoring conducted over a period of 20-30 or more years. For example, growth trends in spruce and pine forests in southern Sweden over a 65-year period clearly indicate a decrease in annual tree ring width. However, data collected between 1960 and 1970 suggest an increase in annual tree ring width.[6] Thus short-term data would lead to very different conclusions regarding overall forest growth than those drawn from 65 years of data collection (Figure 3-1).

Because an ecosystem is comprised of many biological organisms, nonliving substances, and the complex interactions among them, it is unlikely that any single organization—public or private—would have the expertise or the financial resources to monitor it adequately. Thus assessing status and trends in whole ecosystems often requires the cooperation of local, state, and federal agencies. Multiagency cooperation also is valuable for minimizing the duplication of data collection efforts and ensuring effective, efficient data collection, the use of similar data collection methods, and consistent data quality, so that data can be compared over time and space.

Figure 3-1.—Comparisons of Forest-Growth Trends in Southern Sweden, 1910-1974.



Source: Swedish Ministry of Agriculture, Environment '82 Committee, *Acidification Today and Tomorrow*, SMA, Stockholm (1982).

The ability to anticipate future changes in environmental quality is an essential component of this country's environmental policy. If emerging problems and future changes in the condition of the environment can be projected from environmental trends, then long-term national efforts to protect the environment will be much more effective and less costly to implement.

Environmental Data and Trends Today

Recognizing the need for adequate monitoring programs that would identify and detect long-term environmental trends within ecosystems and on regional, national, and global scales, the U.S. government improved its monitoring efforts during the 1980s. These improvements are illustrated by the monitoring programs and networks described in the remainder of this chapter.

One example of the progress made during the 1980s is the National Acid Precipitation Assessment Program (NAPAP), a comprehensive, large-scale, multiagency monitoring program established to monitor and study a specific type of environmental problem—acid rain. Because this program integrated the expertise and unique capabilities of many agencies, it was capable of managing and maintaining long-term monitoring networks to detect trends in environmental conditions within several ecosystems and over regional scales.

Moreover, during the 1980s several different federal agencies developed new monitoring programs, or improved existing ones, to collect environmental data on regional and national scales. In many cases those programs involved cooperation and coordination with other federal agencies.

Finally, a fully integrated, multiagency effort has been established to coordinate U.S. global monitoring and data collection and to cooperate with international global monitoring programs. The U.S. Global Change Research Program demonstrates the nation's commitment to the long-term data collection needed to identify and detect global environmental trends. That program will help generate the scientific information needed to formulate national and international policies to protect the nation's—and the globe's—resources for future generations.

National Acid Precipitation Assessment Program

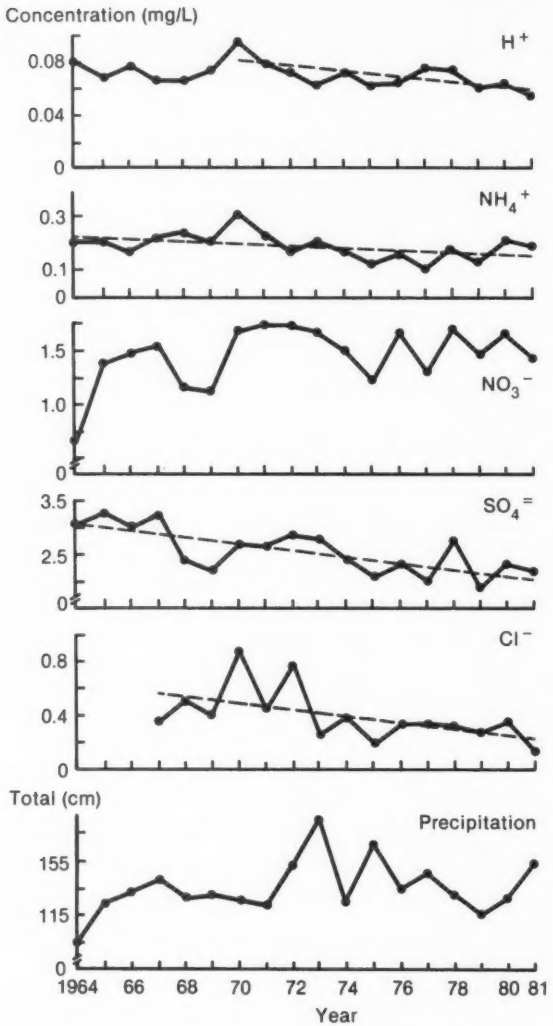
The acid rain problem illustrates how this nation's approach to the collection of environmental data and identification of environmental trends changed in the 1980s from local to regional and national scales and from short-term to long-term time frames. It also demonstrates the change from a single agency to an interagency approach to data collection.

Acid rain, more properly referred to as acidic deposition, is formed when sulfur and nitrogen compounds are released into the atmosphere, usually through the combustion of fossil fuels. In the atmosphere, these compounds are converted to sulfuric and nitric acids, which can be transported hundreds of miles before they return to the ground as acid rain or as dry acidic particles. Lakes and streams, forests, fish and wildlife, monuments and buildings, and human health all can be affected by the deposition of acids from the atmosphere.

In the early to mid-1970s, acid rain and its potential environmental effects attracted the attention of the nation. While some lakes and streams were acidified and some forest damage was apparent, very few long-term data were available to test the hypothesis that surface water acidification or changes in forests over time were a result of acidic deposition.

Therefore, in 1978 the National Acid Deposition Program was established. It was a volunteer effort by universities and other groups to obtain long-term data on acidic deposition in ecosystems ranging from lakes and streams to forests and agricultural fields. Such long-term measurements were deemed critical, because ecosystem acidification as a result of acidic deposition occurs over decades. Long-term measurements were also needed to identify long-term environmental trends and to distinguish between natural short-term variability and trends in environmental conditions caused by human activities. For example, the natural variability in precipitation chemistry data collected in an experimental forest in New Hampshire (Figure 3-2) indicated an increase in sulfate and nitrate concentrations from 1970-1975.[7] The long-term trend over the 15 years of

Figure 3-2.—Annual Volume-Weighted Concentrations of Hydrogen Ion, Ammonium, Nitrate, Sulfate, and Chloride in Bulk Precipitation and Total Precipitation for the Hubbard Brook Experimental Forest in New Hampshire, 1964-1981.



Source: Likens, G.E., "A priority for ecological research," *Bull. Ecol. Soc. Amer.* (1983), 64(4):234-243.

Note: Dashed regression lines are significant at $P < 0.05$.

monitoring, however, clearly indicated a decrease in sulfate and nitrate concentrations in precipitation. Therefore, the short-term, 5-year data would have led to very different conclusions regarding the rates of acidic deposition than the long-term data.

By the late 1970s scientists had raised concerns about the effects of acidic deposition on the environment based on anecdotal studies and theoretical predictions. For example, the National Academy of Sciences indicated that, at then-current rates of sulfur and nitrogen emissions, the number of lakes affected by acidic deposition could double by 1990.[8] That concern over the adverse environmental, health, and welfare effects of acid deposition prompted Congress to pass the Acid Precipitation Act of 1980.[9] Because of concern over the potential impacts of acid rain, Congress required research on the sources, fate, transport, and effects of acidic deposition, as well as economic assessments of those effects and alternative technologies to control or remedy any harmful effects.

Congress also recognized that acid rain was a regional problem that could affect many types of natural ecosystems and man-made resources. Evaluating the cumulative or long-term effects of acidic deposition on the environment would require a range of expertise only available through a coordinated interagency monitoring and assessment program conducted over an extended period of time.

Consequently, an Interagency Task Force consisting of representatives from 11 federal agencies, representatives of 4 national laboratories, and 3 presidential appointees with a range of expertise in the biological, chemical, physical, health, political, and social sciences was formed to address the acid rain problem. This task force guided the development of NAPAP, a comprehensive, 10-year research program to assess the long-term effects of acidic deposition on all ecosystems and in all environmental media.[10]

The creation of NAPAP was a significant step in the evolution of this country's environmental policy. For the first time the expertise of many federal, state, and local agencies was linked together in a long-term, cooperative research program. NAPAP also established comprehensive regional monitoring networks and a framework through which data could be brought together, synthesized, and integrated to define regional environmental trends as a result of acid rain.

Aquatic Effects

Although acid rain affects many ecosystems, particular concern was voiced about its effects on lakes and streams in the United States. Much of the information to support this concern, however, was anecdotal; it originated from studies of a few lakes or streams. No regional estimates of the number of lakes or streams that were acidic or that were sensitive to acidic deposition were available. Therefore, in 1983 the NAPAP Aquatics Effects Task Group designed and conducted a quantitative National Surface Water Survey (NSWS) to answer two questions:

- How many lakes and streams are currently acidic? and
- How many systems might be potentially sensitive to acidic deposition?

The NSWS focused on eight geographic regions of the United States that were considered susceptible to acidic deposition (Figure 3-3). The survey found acidic lakes and streams in some of those regions (Table 3-1), although some of them were naturally acidic or acidic for reasons other than acidic deposition. In addition, the acidic and low pH systems (pH < 5.5) were located in limited geographic areas, and within those areas they were generally restricted even further (such as the mid-Atlantic coastal plain, the New England seaboard lowlands, the southwest Adirondacks, and the northern Florida highlands (see Figure 3-4).

After developing reliable estimates of the number of acidic ecosystems in selected regions, the task group asked how many more aquatic ecosystems might become acidic in the future. Watershed modeling studies were conducted to provide estimates of the time over which future changes might occur. Those studies compared the effects of different rates of acidic deposition that might be associated with various pollution control programs and regulations on aquatic ecosystems. Thus for the first time regionally based watershed models were used to project changes that might occur in the future.

In the Northeast, the models projected little change in the number of acidic lakes over the next 50 years under current

Table 3-1.—Population Estimates of the Number of U.S. Lakes and Streams with Acid-Neutralizing Capacity (ANC) and pH below Reference Values, 1989.

REGION	LAKE OR STREAM	TOTAL NUMBER*	% ANC			pH		
			≤0	≤50	≤200	≤5	≤5.5	≤6
New England	L	4,327	4	20	64	2	6	11
Adirondacks	L	1,290	14	38	73	10	20	27
Mid-Atlantic Highlands	L	1,479	6	14	41	1	6	8
	S	27,692	8	22	48	7	11	17
Mid-Atlantic Coastal Plain	S	11,287	12	30	56	12	24	49
Southeastern Highlands	L	258	<1	1	34	<1	<1	<1
	S	18,928	1	8	52	1	2	9
Florida	L	2,098	23	40	50	12	21	33
	S	1,728	39	70	78	31	50	72
Upper Midwest	L	8,501	3	16	41	2	4	10
West	L	10,393	<1	16	66	<1	<1	1

*Lakes or stream reaches estimated for the region of interest. Percentage times total number of lakes or streams (for example, New England Region 4% × 4,327 = 173) equals actual number of acidic lakes or streams.

Source: Modified from Baker, L., et al., "Current status of surface water acid-base chemistry," page 9-5 in *State of Science and State of Technology*, Irving, P., ed., NAPAP, Washington, DC (1989).

Figure 3-3.—Areas Included in the NAPAP National Surface Water Survey, 1983.

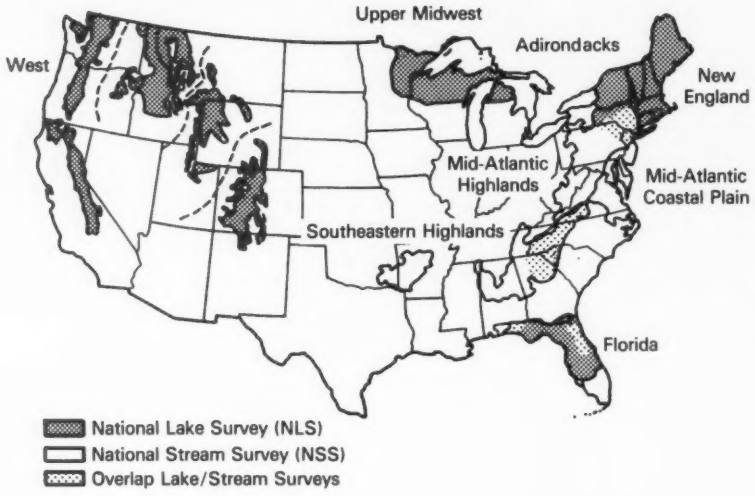
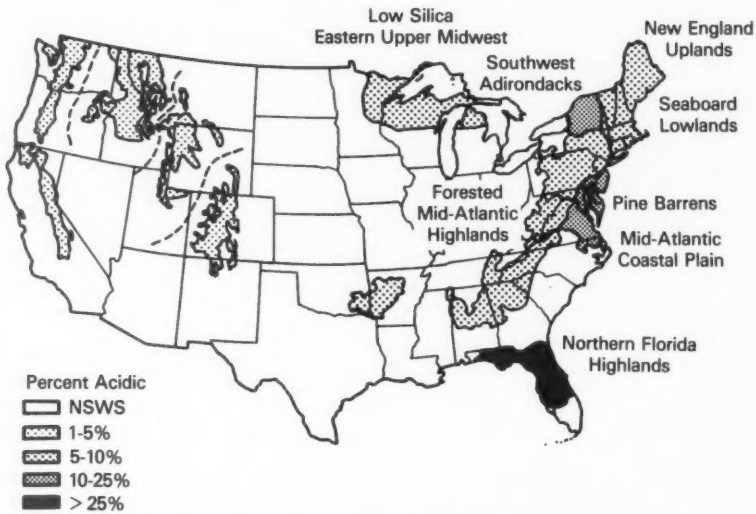


Figure 3-4.—Acidic Surface Waters Identified in the NAPAP National Surface Water Survey, 1983.



Source: Baker, L. et al., "Current status of surface water acid-base chemistry," pages 9-2 and 9-13 in *State of Science and State of Technology*, Irving, P., ed., NAPAP, Washington, DC (1989).

acidic deposition rates. When the rate of acidic deposition was decreased below current deposition rates, the models projected an improvement in lake water quality and a decrease in the number of acidic lakes. In the Southeast, specifically in the Southern Blue Ridge Province, a portion of the Blue Ridge Mountains where no acidic streams have been found, model projections indicated that approximately 10 percent of the streams in this region might become acidic in 50 years under current deposition rates.[11]

Together the NSWS and the watershed modeling studies fostered a quantitative regional perspective of the acid rain problem and provided the information needed to estimate the regional effects of acid rain on aquatic ecosystems. Those estimates resulted from coordinated, collective research conducted by EPA, the Forest Service, the National Park Service, the U.S. Geological Survey, the Fish and Wildlife Service, and the Tennessee Valley Authority.

Ten years of data now have been collected at over 50 lakes and streams within the United States. NAPAP currently is integrating those data with data on emissions, atmospheric transport, forests, agriculture, materials, visibility, human health, and control technologies to assess the economic and environmental effects of acidic deposition. That information also is being used to develop amendments to the Clean Air Act.

As NAPAP draws to a close, federal agencies are recognizing the importance of maintaining the long-term monitoring stations established under NAPAP. Those monitoring stations will be used to assess the effectiveness of emissions controls that might be implemented through Clean Air Act amendments and to determine if environmental conditions are deteriorating, improving, or remaining the same.

Lessons Learned

The value of NAPAP extends beyond what it learned about the causes and effects of acid rain. In fact, many of the lessons learned from NAPAP can be applied to other monitoring programs carried out in the 1990s and beyond.

First, the cooperation of different federal agencies with monitoring responsibilities is critical, because the range of expertise needed to study large-scale environmental problems cannot be found in any single federal agency. Second, statistically designed regional and national monitoring networks and surveys help put large-scale, ecosystem-wide environmental problems in perspective. Third, predictive techniques can be developed, applied to regional problems, and used to assess different regulatory or control strategies. Fourth, monitoring networks that continuously collect ecosystem data nationwide and over a long period of time are critical for obtaining a clear picture of the status and trends in environmental quality. Finally, periodic checks of program progress are necessary to make mid-course changes and maintain program focus.

National Environmental Monitoring

Federal agencies, Congress, and private environmental organizations, such as The Conservation Foundation, the National Wildlife Federation, and the Environmental Defense Fund, have long recognized the need to improve the nation's ability to document the condition of the environment. Congressional hearings in 1984 on the National Environmental Monitoring Improvement Act[12] concluded that, although considerable money has been spent on environmental monitoring, federal agencies could not assess the status of ecological resources or the nation's overall progress in mitigating or preventing adverse ecological effects. In the past decade, articles and editorials in professional journals of the environmental sciences, including the *Bulletin of the Ecological Society of America*, *Ecology*, *Limnology and Oceanography*, *Nature*, *Science*, *Scientific American*, and *Water, Air and Soil Pollution*, have called repeatedly for the collection of more relevant and comparable ecological data and easier access to such data by the public, special interest groups, and the research community.

Over the past decade, many of these criticisms have been addressed through the establishment of new monitoring programs or the improvement of existing monitoring programs. These improvements or additions, in many instances, were the result of interagency coordination and cooperation, including joint operations of monitoring stations and databases. The following discussion of interagency monitoring networks is not intended to be comprehensive. Rather, it illustrates recent progress in the collection of relevant and comparable data by coordinated federal agency efforts.

National Acid Deposition Program/National Trends Network

The National Acid Deposition Program (NADP) monitoring network began operation in 1978. In 1983 the NADP network was incorporated into the National Trends Network (NTN) to form the NADP/NTN network. This network currently consists of approximately 200 wet and dry deposition monitoring stations located throughout the United States, but with a larger concentration of stations east of the Mississippi River. The coverage, however, is limited at high elevations.

The NTN stations are funded by seven federal agencies (the Bureau of Land Management, EPA, NASA, the National Park Service, the Forest Service, the U.S. Geological Survey, and the U.S. Cooperative State Research Service) as well as by several non-federal entities. The quality assurance activities are funded by EPA. The primary objective of the network is to determine the spatial distribution and temporal trends in wet deposition of chemicals in order to assess the effects on terrestrial and aquatic ecosystems. Of the 200 existing stations, 150 are NADP/NTN stations and 50 are NADP-only stations. Samples are collected weekly and analyzed for pH, conductivity, and various cations and anions. Data are stored at Colorado State University and in the Acid Deposition System at Pacific Northwest Laboratory.

Interagency Monitoring of Protected Visual Environments

The Interagency Monitoring of Protected Visual Environments (IMPROVE) is a visibility monitoring program managed cooperatively by EPA, the National Park Service, the Fish and Wildlife Service, the Bureau of Land Management, and the Forest Service. This network, currently consisting of 20 monitoring sites located primarily in the western United States, is intended to assess long-term trends in visual and aerosol air quality. Data is summarized by site on a quarterly basis.

In addition, the National Park Service (NPS) presently monitors visibility in 37 other NPS areas. Sixteen of these areas have IMPROVE-type instrumentation and follow IMPROVE protocols. The remaining 21 stations, known as the NPS National Visibility Trend Monitoring Network, monitor visibility photographically.

National Stream Quality Accounting Network

The Department of the Interior operates and maintains several water quality monitoring networks. For example, the U.S. Geological Survey maintains a comprehensive, nationwide system of stream-gaging stations, groundwater observation wells, and surface and groundwater quality sampling stations.

That system, the National Stream Quality Accounting Network (NASQAN), is an excellent example of recent improvements and modifications in environmental monitoring networks. Started in 1973 with 50 stations, it currently includes approximately 400 stations. The primary objectives of the network are (1) to describe regional and national variability in stream flow and quality on an annual basis, and (2) to account for changes in stream flow and quality. To accomplish these objectives, all stations are operated uniformly with respect to measurement parameters, methods, and quality assurance. The NASQAN network recently was reviewed and revised to improve network efficiency.

National Water Quality Assessment Program

In 1986 the U.S. Geological Survey was charged with testing and refining a National Water Quality Assessment (NAWQA) Program. Although the NAWQA program focuses on one primary element of the environment—water—it also is designed to study the interrelationships of water quality with the health of living resources that depend on water for survival. The program includes biological as well as physical and chemical sampling and analysis. In 1989 the National Academy of Sciences pointed out the need for such a long-term, large-scale national assessment, because "human and environmental health are inextricably linked to our nation's water quality."[13]

The purpose of NAWQA is to describe the current status and long-term trends in the quality of the nation's surface and groundwater resources, and to provide a sound scientific understanding of the primary natural and human factors that affect the quality of these resources. The program will focus on water quality conditions that are large-scale and persistent over time, such as regional degradation of water quality from nonpoint sources. Water quality data will be available to water system managers, government officials, and the public to help evaluate the effectiveness of water quality management programs and predict the likely effects of proposed changes in land and water management practices.

Several federal agencies, including EPA, USDA, and NOAA, have been involved during the planning of NAWQA. Local liaison committees, including representatives of federal, state, and local agencies, have participated in seven pilot projects selected to represent a diversity of hydrologic environments and water quality conditions across the country.

NAWQA has been designed as an operational assessment program. Therefore, in addition to the water quality data to be collected, several types of reports and assessments are planned. Annual reports will discuss water quality issues related to the regional and national findings of the monitoring program. Summaries of water quality status and trends and key findings will be published and updated every 3-5 years.

National Wetlands Inventory Project

Throughout the 1970s and 1980s the federal Fish and Wildlife Service (FWS) has revised its procedures for monitoring the loss of wetlands throughout the United States. The first nationwide survey of wetlands, conducted in 1954, focused on waterfowl wetlands. That survey covered about 40 percent of the continental United States. In 1974 the FWS was directed to design and conduct an inventory of the nation's wetlands and develop and disseminate a technically sound, comprehensive database on their characteristics and extent. By 1979 the National Wetlands Inventory Project (NWI) became operational. In 1982 the survey was completed for the continental United States. This survey estimated that from 1954 to 1974 the average annual rate of loss for the 20-year period was about half a million acres of wetlands. Eighty-seven percent of the loss was due to agricultural conversion.[14]

Updated status and trends information on wetlands was mandated by the Emergency Wetlands Resources Act of 1986. The NWI is currently in the process of updating the national status and trends study from the mid-1970s to the mid-1980s. The FWS is working with the Soil Conservation Service, the Army Corps of Engineers, EPA, state agencies, and private organizations to obtain status and trends data for NWI reports. The FWS will coordinate and integrate the NWI data with the EPA Environmental Monitoring and Assessment Program (EMAP).

Forest Inventory and Analysis/Forest Health Monitoring System

The Forest Service has conducted ecosystem studies and monitoring for over 75 years. Currently, 138 Experimental Forests and Watersheds, including Hubbard Brook, Coweta, and H.J. Andrews, are maintained by Forest Service Research. In addition, the Forest Service has managed a Forest Inventory and Analysis (FIA) system since the 1930s, but in the past it emphasized data related to timber production. Over 100,000 FIA plots are maintained nationwide.

In 1974 the FIA was expanded to provide information on water, wildlife habitat, and recreation in forests, rangelands, and related ecosystems. Moreover, the Forest Service recently has been designing a Forest Health Monitoring (FHM) system in response to concerns about the potential effects of global climatic change on forests and related ecosystems in North America, the tropics, and Europe. The Forest Ecosystems and Atmospheric Pollution Research Act of 1988[15] directs the Forest Service to design and implement a monitoring program to track long-term trends in the health and productivity of forest ecosystems in the United States. The FHM program will provide information on forest growth, forest mortality, forest distribution and structure, canopy conditions, soil conditions, and surface water conditions. Additional measurements that may help interpret ecosystem changes include environmental toxins, weather data, and basic forest attributes such as biomass and density of trees.

There are three integrated tiers in the program: Detection Monitoring, Evaluation Monitoring, and Research Monitoring. The Detection tier is designed to detect unexpected changes in forest condition. Detection of an abnormal trend will trigger the Evaluation tier, which will assess and evaluate potential causes of unexpected changes. Research Monitoring will provide long-term information to fully understand these changes on an ecosystem basis. The FHM field program is being initiated in the New England states in 1990 in conjunction with cooperating state forestry organizations and the EPA Environmental Monitoring and Assessment Program (EMAP).

National Status and Trends Program/Strategic Assessment Program

The National Oceanic and Atmospheric Administration (NOAA) carries out a range of monitoring, research, and assessment programs related to marine environmental quality. Current activities include (1) a National Status and Trends Program that conducts nationwide monitoring of marine environmental quality in coastal waters, and (2) a Strategic Assessment Program that develops comprehensive data and information, both historical and contemporary, on marine ecosystems and environmental quality to support strategic assessments of national marine environmental quality problems.

The National Status and Trends (NS&T) Program for Marine Environmental Quality was initiated in 1984 to monitor the status and long-term trends in concentrations of key contaminants and biological indicators of contaminant effects in the nation's coastal and estuarine environments. The NS&T Program includes the Mussel Watch and Benthic Surveillance Projects and a national quality assurance project. The objectives of the NS&T Program are to measure toxic contaminants and other indicators of environmental quality in a nationwide network of representative estuarine and coastal marine sites.

The Mussel Watch Project monitors various pollutants in the tissue of oysters and mussels as well as the pollutant levels in associated sediments in estuaries and along the coasts of the United States. Sampling is conducted regularly at about 250 sites. The Benthic Surveillance Project monitors the same pollutants in tissues of bottom-dwelling fish and associated sediments but for a fewer number of sites nationwide. These programs have noted trends in several pollutants over the past 10 years. For example, lead concentrations in oysters and mussels are generally lower now than they were 10 years ago, while copper concentrations are higher in mussels (but not oysters) than 10 years ago. The lead decrease can be attributed to the phase-out of lead in gasoline. While no single source can be identified for copper, copper consumption and use in the United States is higher now than it was 10 years ago.

NOAA also carries out a Strategic Assessment Program, which is designed to make maximum use of existing data, information, and expertise and to incorporate this information into national and regional assessments of coastal resources and environmental quality. Data are evaluated, interpreted, and compiled in a series of databases designed to provide easy access, facilitate computer mapping and comprehensive analyses, and provide information in a usable atlas format.

During 1989 a joint EPA-NOAA committee was established to coordinate the coastal and estuarine monitoring programs of the two agencies. The goal is to coordinate and integrate the NS&T Program with EMAP to produce a single, well-coordinated coastal and estuarine monitoring program supported by both agencies. NOAA also has participated with the U.S. Geological Survey in the development of the NAWQA Program to ensure compatibility of sampling approaches and analytical methods.

Long-Term Ecological Research Sites

In 1980 long-term ecological research was advanced by the National Science Foundation with the funding of six Long-Term Ecological Research (LTER) Sites. Currently there are 17 sites nationwide; those sites were selected to represent major North American ecosystems, such as desert, prairie, tundra, forest, small stream, large river, lake, and estuarine ecosystems. Sites vary in size from a few thousand to several thousand hectares. LTER sites are well-suited for studying how ecosystems respond to stress, including global climate change. On many LTER sites, long-term field experiments are underway to study system stability and productivity, both on temporal and spatial scales. Examples include studies of the biogeochemistry of lakes in relation to their location within drainage basins and the effect of sea level rise on terrestrial nutrient flux.

Long-term direct experiments involving disturbance by fire, grazing, and manipulation of nutrients, pollutants, and water are emphasized at most sites. Retrospective studies, based on the techniques of paleolimnology and paleoecology, are used at several sites to place ecosystem change and disturbance in his-

torical context. Several LTER sites also incorporate a hierarchy of spatial scales to provide a spatial perspective on ecosystem changes in addition to temporal changes. These long-term process-oriented sites help scientists understand the changes in regional patterns observed in other monitoring networks.

National Environmental Research Parks

The Department of Energy has set up six National Environmental Research Parks (NERPs) to provide protected land areas for research and education in the environmental sciences. This program develops methods for monitoring and assessing the environmental impacts of human activities, predicting the environmental impacts of proposed and ongoing energy development, demonstrating the impacts of various energy activities on the environment, and minimizing adverse effects.

NERP sites are located in representative ecosystems throughout the United States. Each site contains protected natural areas (experimental controls or reference areas) and examples of man-altered systems such as nuclear and fossil fuel power plants, heated ponds, tree plantations, cultivated fields, and land disturbed by other energy or construction activity. Generally, several distinct ecosystems and ecotones exist in each NERP. The Los Alamos site includes ponderosa pine, pinyon-juniper, juniper-grassland, and mixed conifer vegetation communities. NERP sites range in size from 5,500 to 230,000 hectares.

Specific research projects on NERP sites vary, depending on the attributes and problems associated with each site's ecosystems. For example, the Oak Ridge site is used for research on atmospheric deposition, biogeochemical cycling of nutrients and trace elements, and stream and watershed dynamics, whereas the Los Alamos site is used to study ecological characterizations fundamental to addressing environmental compliance.

Many of the NERP sites have extensive long-term databases; data (especially related to climate) were collected at those sites before the establishment of the NERP program. For example, 42 years of continuous precipitation measurements and

20 years of continuous wind and solar radiation measurements have been taken at the Los Alamos site. Not only do those databases serve as valuable baselines against which to measure ecological changes or trends, they also allow new research projects to be superimposed, thus allowing more rapid, cost-effective, and accurate data collection.

Environmental Monitoring and Assessment Program

The EPA Science Advisory Board recommended in 1988 that an interagency program be initiated to monitor ecological status and trends, as well as to develop innovative methods to anticipate emerging environmental problems. On the recommendation of the Science Advisory Board, EPA launched the Environmental Monitoring and Assessment Program (EMAP) to build on the monitoring networks of other federal agencies.

EMAP was established in 1989 as an interagency program to collect data that help answer the following questions:

- What is the current status, extent, and geographic distribution of the nation's ecological resources?
- What proportions of these resources are degrading or improving, where, and at what rate?
- What are the likely causes of adverse effects?
- Are adversely affected ecosystems responding as expected to control and mitigation programs?

Although agencies like the U.S. Geological Survey, Forest Service, and National Oceanic and Atmospheric Administration have long-term monitoring programs, those programs monitor only a portion of the nation's ecological resources. To determine its health, an entire ecosystem must be monitored, not just one component. EMAP provides a framework within which various federal, state, and local agencies, academia, and other participants can bring together a range of expertise and resources to

collect the data needed to document the status and trends in environmental conditions across whole ecosystems.

The assessment of ecological conditions over time is critical for evaluating the effectiveness of regulatory programs and for determining the nation's future research needs. The information generated by EMAP will be used not only to describe ecological conditions, but also to identify potential sources of ecological stress and degradation. For example, it may be possible to associate an increase in the proportion of estuaries exhibiting periods of low dissolved oxygen and fish kills with an increase in the cumulative discharge of various oxygen-demanding chemicals. Although individual industrial or municipal sources of pollution may meet discharge permit requirements, the cumulative impacts occurring on a larger scale may contribute to the decline of dissolved oxygen levels.

Global Environmental Monitoring

Because global processes are extremely complex, it is difficult to distinguish between man-induced changes (such as global temperature changes due to increased atmospheric concentrations of CO_2 and other trace gases) and natural variability (such as long-term temperature changes resulting from natural climatic variations). National governments and international organizations have recognized that to assess the health of the complex global ecosystem and to project future changes due to either man-made or natural causes requires environmental monitoring of (1) global ecosystems such as oceans, the biosphere, and the atmosphere, (2) global processes and dynamics such as ocean currents and biogeochemistry, and (3) global interactions such as between ocean and atmosphere. International and national scientific communities and intergovernmental environmental research groups, including the National Academy of Sciences (NAS), the International Council of Scientific Unions (ICSU), and the World Meteorological Organization (WMO), have ad-

vised national governments of the need for monitoring the global ecosystem. Monitoring programs at the regional and national scales are inadequate for identifying global environmental changes and trends.

The effects of human activities on global processes can become apparent within decades. Often, however, they occur in conjunction with natural variability on similar time scales. Thus it may be difficult to differentiate anthropogenic from natural changes without a substantial amount of data collected over a long time period.

Consequently, global data collection and measurements often must be sustained over decades. Additionally, global processes and conditions must be measured simultaneously at different places to be useful for defining and understanding global trends.

Just as no one federal agency is capable of conducting national environmental monitoring, no one country has the comprehensive expertise or resources to monitor the global ecosystem. National and international coordination is essential to identifying and understanding environmental trends that affect all countries.

Monitoring and Research Programs

In the United States, many federal agencies monitor changes in the global ecosystem. Significant contributions to global research, specifically in the earth sciences, atmospheric sciences, oceanic studies, biological sciences, and climate studies, have been made by the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the Department of Energy (DOE), the Office of Naval Research, the U.S. Geological Survey, and the National Science Foundation (NSF), among others.

Much of this work has been carried out through sophisticated space research, earth-based measurements, and the development of models simulating global processes. Until the 1980s global research and monitoring was accomplished largely through single agency-sponsored programs and within a single

scientific discipline. For example, NASA space-based measurements of wind patterns provided a comprehensive understanding of global atmospheric currents.

Over the past decade, interdisciplinary, interagency global research and monitoring programs have advanced the acquisition of global data and the knowledge of global conditions, changes, and trends. Moreover, federal agencies and their programs have been tied closely to the programs of intergovernmental and international science organizations. For example, in 1978-1979 the National Climate Program was implemented.[16] This program was the first cooperative endeavor among federal and state agencies, regional and private institutions, academia, and the private sector to develop global climate monitoring programs with a predictive rather than a responsive focus. The National Climate Program is closely tied to international monitoring and research efforts, including the WMO World Climate Program, the UNEP World Climate Impacts Program, and the ICSU Scientific Committee on Ocean Research and Scientific Committee on Problems of the Environment.

In 1983 NASA established the Earth Systems Sciences Committee, which recommended a tri-agency program for global Earth system studies by NASA, NSF, and NOAA.[17] A few years later, NOAA and NSF set up research programs investigating global climatic change. In 1986 NSF established its Global Geosciences Research initiative, and NOAA began its Climate and Global Change initiative.

In 1986 the International Council of Scientific Unions (ICSU) endorsed the International Geosphere-Biosphere Program, a new effort to study global change and to complement the existing World Climate Program. In the same year the United States recognized the need to monitor all aspects of global change and to coordinate with international monitoring and research programs. In 1987 the Presidential Science Advisor established a federal interagency group, the Committee on Earth Sciences (CES), to develop a national strategy for addressing global change research and development issues. (See Table 3-2 for a list of CES members.)

Table 3-2.—Membership of the Committee on Earth Sciences, May 1989.

Council on Environmental Quality (CEQ)
Department of the Interior (DOI)
Department of State (DOS)
Office of Management and Budget (OMB)
Department of Agriculture (USDA)
Environmental Protection Agency (EPA)
National Aeronautics and Space Administration (NASA)
Department of Defense (DOD)
Department of Energy (DOE)
Office of Science and Technology Policy (OSTP)
National Science Foundation (NSF)
Department of Commerce (DOC)
Department of Transportation (DOT)

Among other things, CES has been charged with the following tasks:

- Review federal research and development programs in earth sciences, including national and international programs;
- Improve planning, coordination, and communication among federal agencies engaged in earth sciences research and development;
- Identify and define earth sciences research and development needs;
- Develop and update long-range plans for the overall federal research and development effort in earth sciences;
- Address specific programmatic and operational issues and problems that affect two or more federal agencies; and
- Develop the Administration's response to the NSF Authorization Act of 1987 calling for a report to Congress on the establishment of an International Year of the Greenhouse Effect in 1991.

U.S. Global Change Research Program

In January 1989 the Committee on Earth Sciences (CES) presented a government-wide plan for integrating U.S. global change research in *Our Changing Planet: A U.S. Strategy for Global Change Research*. This report outlined the goals and objectives of the U.S. Global Change Research Program and recommended the development of a comprehensive research plan that would integrate existing federal global change monitoring and research activities.

In July 1989 the CES developed an initial research plan for the U.S. Global Change Research Program. The purpose of this plan, detailed in *Our Changing Planet: The FY 1990 Research Plan*,[18] was to facilitate the planning and coordination of the federal research and budgetary activities of the Global Change Program. The plan was based on recommendations and research plans developed over the past several years by the national and international scientific community, including the National Academy of Sciences and ICSU; national governments, such as those representing the United Kingdom, Japan, Brazil, and the Soviet Union; intergovernmental coordinating bodies, such as the U.N. Intergovernmental Panel on Climate Change; and international environmental organizations, including WMO and UNEP. The plan is intended to interface with other national and international programs, including the National Climate Program, the World Climate Program, the International Geosphere-Biosphere Program, the Tropical Ocean and Global Atmosphere Program, and the International Lithosphere Program.

The 1990 Global Change Research Plan also has drawn upon many of the lessons learned from environmental monitoring in the United States since the 1970s. It has brought together a host of federal agencies whose programs are complementary and share a common scientific method, framework, and goal. It is a large-scale, global approach that provides the structure for long-term monitoring. One of the key scientific objectives of this multiagency monitoring and research program is to provide the predictive capabilities necessary to determine future global data needs and formulate effective environmental policies.

Scientific Objectives

The U.S. Global Change Research Program outlined in the FY 1990 Research Plan has three interdependent scientific objectives:

- Monitoring global environmental trends and acquiring global data,
- Understanding global processes and the interactions of the individual components of those processes, and
- Projecting future global changes and the impacts of such changes.

Three key scientific questions have formed the basis of these objectives:

- What global changes have occurred in the past and are occurring now?
- What physical, geological, chemical, biological, and social processes are involved in influencing global change and its environmental impacts?
- How well can global change and its impacts be predicted?

The goal of the U.S. Global Change Research Program is to provide an accurate and sound scientific basis for informed decisionmaking related to global environmental issues (see Figure 3-5). Reliable scientific data and predictive capabilities will be essential components of any national or international policies developed in response to the effects of potential climatic change.

To obtain accurate and reliable data, CES has evaluated existing global research programs and monitoring networks and assisted in coordinating, planning, and integrating scientific research at three levels of scientific discipline: single disciplinary studies, interdisciplinary studies, and integrated studies (see Figure 3-6). The U.S. Global Change Research Program is working to integrate scientific disciplines and agencies critical to understanding the global ecosystem.

Figure 3-5.—Goal of the U.S. Global Change Research Program.

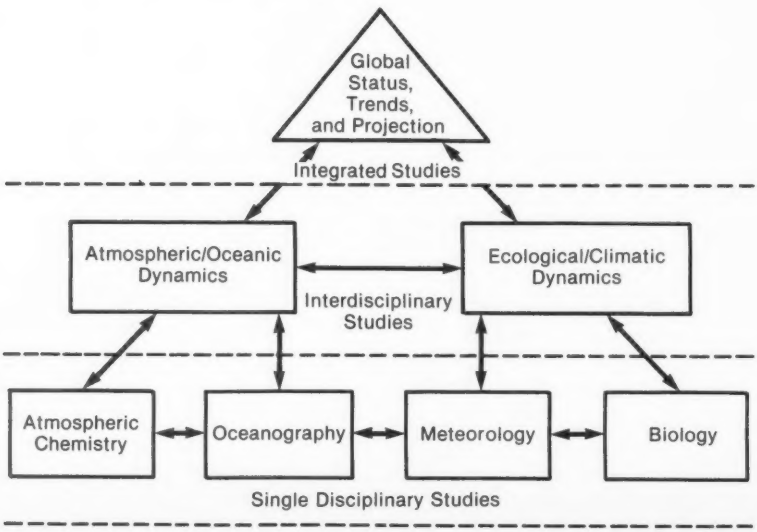
U.S. Global Change Research Program Goal

Recognizing that effective and rational response strategies to environmental issues can be built only on sound scientific information, the overarching goal of the U.S. Global Change Research Program is:

To gain a predictive understanding of the interactive physical, geological, chemical, biological, and social processes that regulate the total Earth system and, hence, establish the scientific basis for national and international policy formulation and decisions relating to natural and human-induced changes in the global environment and their regional impacts.

Source: Committee on Earth Sciences, *Our Changing Planet: The FY 1990 Research Plan*, Report by CES on U.S. Global Change Research Program, Office of Science and Technology Policy, Executive Office of the President, Washington, DC (1989), page 10.

Figure 3-6.—The Scientific Approach to the U.S. Global Change Research Program.



Several federal agencies are involved in global monitoring and data collection. Each brings unique expertise to the U.S. Global Change Program (see Table 3-3), and each plays an important part in advancing the nation's knowledge of global conditions and trends.

Table 3-3.—Major Federal Agencies Involved in Global Monitoring and Research Programs.

AGENCY	AREA OF EXPERTISE
National Oceanic and Atmospheric Administration (NOAA)	Climate Studies Weather Prediction Ocean Studies Data Management Atmospheric Studies Stratopheric Ozone
Department of Energy (DOE)	Climate and CO_2 Precipitation Chemistry Atmospheric Chemistry Ecosystems Research Geosciences
Department of the Interior (DOI)	Ecosystem Modeling Land and Water Use
U.S. Geological Survey (USGS)	Remote Sensing Studies Hydroclimatology Hydrologic Systems, Processes, and Modeling Spatial Data Collection Water Resources Information and Data Management Land Surface Geology Geography
Minerals Management Service (MMS)	Arctic Species Ocean Circulation and Heat Flux
Fish, and Wildlife Service (FWS)	Wetlands Biological Diversity Wildlife Fish Threatened and Endangered Species Habitat
National Park Service (NPS)	Ecological Research Man and the Biosphere Program Vegetation Classification Populations Communities Natural Resources Earth History

Table 3-3.—Major Federal Agencies Involved in Global Monitoring and Research Programs (cont.).

AGENCY	AREA OF EXPERTISE
Bureau of Land Management (BLM)	Fire Weather/Climate
	Wilderness Management
	Rangeland
	Wildlife
	Fish
	Threatened and Endangered Species
Environmental Protection Agency (EPA)	Air Quality
	Climate Scenarios
	Acidic Deposition
	Atmospheric Research
	Terrestrial Ecosystems
	Quality Assurance
	Water Quality Effects on Ecosystem Processes
	Pesticides Transport and Ecosystem-Level Effects
	Toxic Substances Research
	Environmental Monitoring and Assessment Program
	Human Health
	Research/Policy Analysis
	Domestic Regulatory Actions
National Aeronautics and Space Administration (NASA)	Earth Observing System
	Atmospheric-Surface Interactions
	Climate Systems
	Greenhouse Effects
	Remote Sensing
	Weather Cloud-Radiation Processes
	Hydrological Cycle Components
	General Calculation Models
	Biosphere-Atmosphere Interactions
	Sea Ice and Ice Sheets
National Science Foundation (NSF)	Atmospheric Chemistry
	Biological Diversity
	Climate Studies
	Earth History
	Ecosystems Research
	Geosciences in Polar Regions
	Ocean Studies
	Regional Geography
	Social and Economic Research
	Solar-Terrestrial Studies

Agency Expertise

The National Oceanic and Atmospheric Administration (NOAA) has been involved in climate and oceanography studies for two decades. NOAA monitors the oceans, measures global sea level, and monitors global climate. More specifically, NOAA monitors and observes changes in climate system processes and their effects on marine ecosystems. Because NOAA has extensive expertise in modeling climate systems, it has the capability to project future climate changes. NOAA also is responsible for acquiring the climate data obtained by all agencies involved in global research and for distributing that data in a useable form.

The Department of Energy (DOE) also conducts research on global climate systems. However, DOE pays special attention to CO_2 and other air pollutants emitted when energy is used. DOE has major responsibility for predicting climate change in response to increased levels of CO_2 and methane. DOE research also focuses on ways to detect global warming at an early stage.

The Department of the Interior (DOI) has a number of agencies involved in both single-disciplinary and interdisciplinary studies to detect trends in the nation's natural resources. Because of the many DOI agencies involved in global data collection, the department's responsibilities are extraordinarily broad.

The U.S. Geological Survey (USGS), with expertise in geological and hydrological sciences, is primarily responsible for monitoring surface water systems and for collecting data on land surfaces, geology, and geography. The USGS will continue to measure land surface features and collect spatial data through its remote sensing studies.

The Fish and Wildlife Service (FWS) collects data on biological diversity, wetlands inventory, migratory birds, wildlife, fish, threatened and endangered species, and changes in species habitat. The Outer Continental Shelf (OCS) Environmental Studies Program, administered by the Minerals Management Service (MMS), collects similar data for the marine and coastal environments. The National Park Service (NPS), as steward of some of the nation's most remarkable natural and environmental resources, is chiefly involved in ecological research, including vegetation classification, population and community studies, the Man and the Biosphere Program, and data collection on the

Earth's history. The Bureau of Land Management (BLM) is largely responsible for monitoring rangelands within the United States, monitoring fire-weather-climate interactions, and collecting data for wilderness management. The MMS collects information and studies key Arctic marine mammals and ocean and heat circulation in the nearshore domain, including the Gulf of Mexico. In addition, DOI has a program to develop species and ecosystem models and methodologies to predict changes in land, water, and other resources and to estimate socioeconomic changes.

The Environmental Protection Agency (EPA) also has diverse responsibilities in the U.S. Global Change Research Program. As part of its mission to protect the environment and human health, EPA conducts research on ecological, environmental, and human-health consequences of global change. EPA also monitors air quality, emissions sources, atmospheric chemistry, and biological and ecological resources through programs such as EMAP and the Global Climate Change Program.

The National Aeronautics and Space Administration (NASA) has been involved in monitoring global climate change and global processes for many years. NASA is chiefly responsible for the continued development and use of sophisticated Earth-observing systems, satellites, and instruments to monitor and collect global data from space. NASA satellites allow the collection of data and global monitoring of the whole planet. Among other areas of observation, NASA monitors atmospheric, oceanographic, and land use systems and processes. Through its Earth Systems Science Program, NASA conducts earth sciences research from space.

The National Science Foundation (NSF) is responsible for maintaining basic research in all areas of earth, atmospheric, and ocean sciences, including the relevant biological and social sciences and research in the polar regions. The NSF role in the interdisciplinary U.S. Global Change Research Program emphasizes ground-based studies on regional and global scales, large-scale field programs, interpretation and use of remotely sensed data and geographic information systems, theoretical and laboratory research, facilities support, and the development of numerical models.

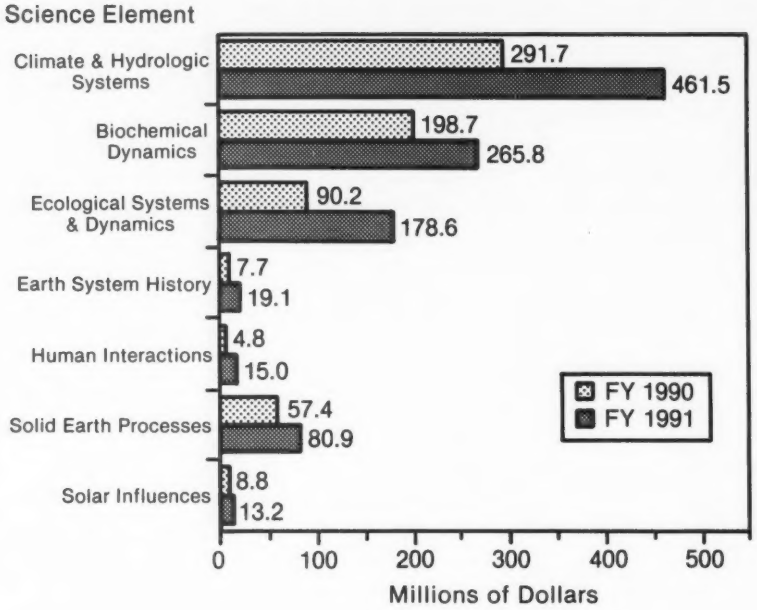
The planning, coordination, and implementation of research programs is carried out through the Directorate for Geosciences, the U.S. Antarctic Program, and the Directorate for Biological, Behavioral, and Social Sciences. Research activities are conducted by scientists and engineers in the nation's universities and colleges and in other institutions. NSF provides support to these researchers in response to peer-reviewed proposals. Planning of the research components is carried out through interactions among NSF program staff and advisory committees and other agencies, the nation's scientists and the National Academy of Sciences, and other national and international committees and scientific organizations.

The U.S. Department of Agriculture (USDA) is conducting research to assess the effects of global change on world agriculture, specifically on the worldwide production of food and fiber crops and on forests. The Forest Service is chiefly responsible for conducting research on the effects of global changes on the Earth's forest ecosystems and their relationships with other ecosystems.

The Department of Defense (DOD) is indirectly involved in the U.S. Global Change Research Program. DOD is conducting mission-related research that provides information on global processes that affect defense operations, tactics, and systems. While not directly tied to global change research, many DOD projects help other federal agencies reach their global change goals. For example, through the Office of Naval Research, DOD collects oceanographic data. The DOD Office of the Oceanographer of the Navy also is conducting long-term oceanographic observations that will contribute to the research and monitoring goals of other agencies.

In FY 1990 the budget for the U.S. Global Change Research Program is $659.3 million. The President's 1991 budget proposes a $1,034 million budget for global change research, an increase of 57 percent (see Figure 3-7). This increase demonstrates the nation's commitment to collect accurate global environmental data and to identify and predict future global environmental trends and to sustain long-term global monitoring programs.

Figure 3-7.—U.S. Global Change Research Program Budget by Science Element.



Source: Committee on Earth Sciences, *Our Changing Planet: The FY 1991 U.S. Global Change Research Program*, Executive Office of the President, Washington, DC (1990).

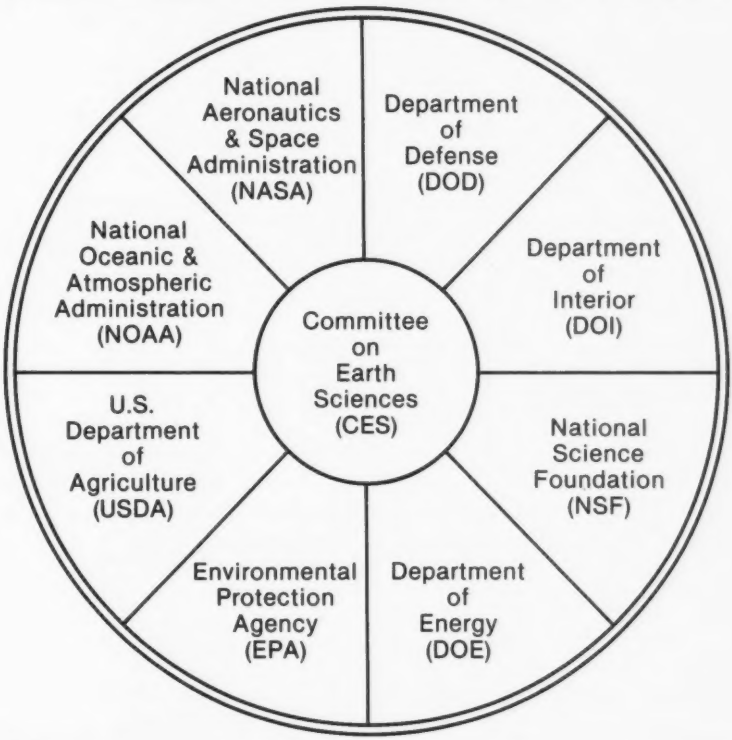
Committee on Earth Sciences

Critical to the success of national and international global monitoring and research efforts is an effective mechanism for federal program oversight, management, and coordination. Such a mechanism increases the overall effectiveness and productivity of the nation's interagency global monitoring and research efforts, fosters unified progress, and maintains international cooperative efforts.

In the United States, CES fulfills this very important role. Because CES is comprised of representatives from several dif-

ferent federal agencies, each with distinct capabilities and expertise, it is able effectively to integrate the scientific resources of the federal government. Each federal agency represented on CES is involved in global programs, either through the collection of global data, the direction of global scientific research, or global policy analysis. Through CES, they coordinate their expertise and programs. Thus CES is at the center of the nation's comprehensive, long-term, multiagency effort to conduct global monitoring and trends research (Figure 3-8).

Figure 3-8.—Structure of the U.S. Global Change Research Program.


National Aeronautics & Space Administration (NASA)
Department of Defense (DOD)
Department of Interior (DOI)
National Science Foundation (NSF)
Department of Energy (DOE)
Environmental Protection Agency (EPA)
U.S. Department of Agriculture (USDA)
National Oceanic & Atmospheric Administration (NOAA)
Committee on Earth Sciences (CES)

Furthermore, CES is instrumental in maintaining linkages between U.S. agencies and international global change programs administered through other governments, such as the United

Kingdom's National Environmental Resource Council, and international scientific organizations, such as the International Council of Scientific Unions, the World Meteorological Organization, the U.N. Environment Program, the U.N. Education, Scientific, and Cultural Organization, and the European Space Agency. International partnerships between scientific and governmental organizations are the key to global monitoring and the identification of global environmental trends.

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June 1, 1987

On June 1, 1987, a driver pulled into a salvage yard in Illinois and unhitched a 12- by 32-foot trailer. Inside the trailer was a fully equipped laboratory that included a gas chromatograph, a sophisticated instrument designed to detect minute concentrations of pollutants in soil, water, and air. This instrument can routinely detect many environmental pollutants present at concentrations of no more than parts per billion. The mobile laboratory that arrived at the Illinois salvage yard in 1987 was owned by a private firm under contract to the Illinois Environmental Protection Agency to clean up the site. The cleanup contractor used the mobile laboratory extensively over the next year, routinely analyzing 15-20 samples per day.

In addition to highly sophisticated detection and measurement instruments, the contractor also used an advanced cleanup technology. The salvage yard, which had been abandoned by its owner, was heavily contaminated with PCBs and other toxic pollutants. As part of the cleanup plan, the contractor incinerated contaminated soil on site using a mobile "rotary kiln incinerator." The contractor excavated contaminated soil from the salvage yard and fed it into the kiln (a rotating chamber), where it was mixed with air and subjected to very high temperatures to destroy the PCBs. After treatment, the soil was filled back in at the site. Exhaust gases from the kiln were passed into a secondary chamber to complete the destruction of the contaminants. They then were treated prior to release into the atmosphere. Over 8,500 tons of PCB-contaminated soil were successfully processed, and the rotary kiln incinerator destroyed and removed 99.99999 percent of the PCBs, while meeting all applicable state and federal emissions control requirements.

CHAPTER 4

Environmental Science and Technology

Environmental pollution is a byproduct of technological and economic development. However, while technology is at least partially a source of environmental problems, it also is part of the solution. Since the 1970s this country's scientific and technological capabilities to detect and respond to environmental problems have expanded enormously.

For example, scientific instruments that detect, identify, and quantify contaminants in air, water, and soil are much more precise than those available 20 years ago. The standard methodologies for using such instruments have improved as well. Today's capabilities for understanding how chemical contaminants travel—under the ground, in surface water, in the atmosphere—how they are transformed as they travel in the environment, and how they reach humans, plants, and animals also have advanced enormously over the past two decades.

Moreover, scientific and technological developments have led to the development of new environmental control technologies. Consequently, many types of pollution can be controlled far more effectively than in 1970. Technologies and production process changes that minimize creation of pollutants in the first place also have evolved.

Part of the nation's response to environmental problems requires strong, well-funded programs to perform scientific research—to better characterize and understand pollution problems and how they interconnect—and to develop technologies to clean up or prevent pollution problems.

Environmental research and development (R&D) involves a range of public and private institutions in a partnership of interests and efforts. Over the past decade, several laws have been enacted to help promote such partnerships between the private and public sector. For example, a new part of the Superfund program, expressly designed to promote public and private sector cooperation, is helping to speed the development of innovative hazardous waste site cleanup technologies. Because many environmental problems are not limited to national boundaries, and because technical expertise can be found throughout the international community, international transfers of technology and international cooperation on R&D are becoming increasingly important as well.

Historical Perspective

Because environmental science and technology is a very broad field, it is difficult to generalize about its status. However, the technological capabilities of the 1970s were rudimentary compared to today. Government agencies and industry had relatively poor capabilities for detecting and measuring pollution in the soil, water, and air, and they had very few technologies for reducing the discharges of harmful substances or for cleaning up pollutants that had entered the environment.

Two decades ago, for example, it was relatively difficult for scientists to test for the presence of environmental contaminants. Scientists were able to detect most chemical contaminants only if they were present at relatively high levels of concentration—in parts per thousand. Because many contaminants cause substantial increased health risks to humans even at concentrations far less than parts per thousand, detection and measurement technology in 1970 was inadequate.

Some research had been performed to model the transport and fate, or transformation, of pollutants in air, water, and land. Some of the basic concepts and mathematical equations developed by 1970—for example, equations governing diffusion of pollutants in the air—are still used by modelers today. However, the modeling capabilities available then simply were not sufficient to support aggressive environmental programs.

For one thing, relatively few models had been developed, and relatively little monitoring data were available to help model developers verify the accuracy of their models. In addition, most models were very cumbersome to use. Most transport and fate models were not computerized, primarily due to the expense and relative inaccessibility of computers. Moreover, in 1970 neither the government nor industry used modeling to support environmental decisionmaking, so most model researchers had not yet focused on the types of problems that are commonly modeled today, for instance, the transfer of contaminants among environmental media and human exposure to contaminants.

In 1970 few pollution control technologies were ready for commercial application. For example, the scrubbers used today to clean flue gases from the smokestacks of coal-burning power plants were still being tested in laboratories. Although mechanical collectors were controlling some particulate emissions, electrostatic precipitators and fabric filters were not widely used, and integrated solutions were not even on the drawing board.

Automobile pollution controls were similarly in their infancy. Positive crankcase ventilation (PCV) systems, which reduce emissions of volatile organics, had been introduced in the 1960s, but major advances like catalytic converters and the use of engines that burned unleaded fuel had not yet occurred. Finally, hazardous waste control and remediation technologies were not even in their infancy. Few people had realized there was a

groundwater contamination problem, much less developed technologies for determining the extent and nature of a contamination plume or for cleaning one up.

In addition, in 1970 very little collaboration was taking place among different sectors of the economy in developing new pollution control technologies and transferring such expertise (for example, from government to industry or from one country to another). The concept of a major industrial firm collaborating with the U.S. government to develop a particular kind of pollution control technology was unheard of in the 1960s, although collaboration between industry and government on space exploration was extensive. However, in 1970 U.S. government agencies and private firms were not accustomed to looking abroad for innovative or state-of-the-art expertise in pollution detection, pollution control, or pollution cleanup technology, because such expertise also was rare in the global marketplace.

Environmental Science and Technology Today

Detection and Measurement Technology

Over the past 20 years, substantial improvements have been made in the capabilities of scientists to identify and measure pollutants in the environment. Scientific tools available today include:

- Qualitative analyses to identify the types of substances, such as chemical groups and specific chemicals, present in soil, air, and water;
- Quantitative analyses to determine how much of each substance is present in samples; and
- Speciation or characterization to establish details of the chemical forms of such substances and the manner in which the substance is present in the sample. For example, is the substance evenly distributed within soil particles? Or is it present at higher concentrations on the surface of the soil particles—thus increasing potential exposures to humans, plants, or animals?

Scientists now can detect some pollutant concentrations in the parts-per-billion or parts-per-trillion range. (One part per billion is analogous to one second of time in 32 years.) Twenty years ago, such pollutants could be detected only when present in the parts-per-million or parts-per-thousand range.

Applications

The ability to detect and measure pollutants is an essential component of many environmental assessment, control, and cleanup activities. Pollutant detection and measurement are essential for a number of purposes:

Background Sampling

Measuring natural or "background" concentrations of selected substances provides the baseline against which to measure either improvements or deterioration in environmental quality. For example, a state environmental agency considering whether to issue a permit for a new facility that will discharge wastewater into a river needs to understand the types and levels of pollution currently in the river.

Pollutant Discharge Measurements

Measuring the amount and rate of pollutant discharges from known sources is at the heart of many permit-based programs, and it is part of virtually all compliance and enforcement programs for point sources. For example, virtually any facility that discharges a significant amount of wastewater into a navigable water body—river, lake, stream, estuary, or ocean—is required to obtain an EPA-issued or state-issued permit. Permits establish limits on the amounts and concentrations of pollutants that the facility is allowed to discharge and require each facility to take samples of discharges, determine the presence and concentrations of all pollutants specified in the permit, and report those data to the state and EPA. In addition, state or federal regulators will take samples and perform measurements periodically as a check on such self-reporting or in response to suspected violations of permit conditions. (See also Chapter 5 of this report: "Enforcement.")

Hazardous Waste Identification and Measurement

Identifying and measuring substances present in hazardous waste sites or that might be escaping from such sites are part of virtually all phases of federal, state, or private cleanups of such sites. For example, detection and measurement are essential to the assessment of the site: What types of pollutants are present and at what levels of concentration? Are any pollutants from the site leaching into the groundwater, making their way into vegetation surrounding the site, or evaporating—"volatilizing"—into the air? At what rates and concentrations? Answers to such questions help regulators determine whether a cleanup action is warranted, and they help establish cleanup priorities, that is, which sites should be cleaned up first.

Such information helps guide the selection of an appropriate cleanup method. Pollutants also must be measured while cleanup is taking place to measure progress and to determine when cleanup goals for the site have been achieved. After the cleanup is finished, long-term monitoring—such as periodic measurement of pollutants in groundwater surrounding the site—provides an early warning of any possible resurgence of problems associated with the site.

Pollutant Identification

Detection and measurement technology is also used to identify pollutants that might be responsible for observed environmental insults. In response to events such as a fish kill, the unexplained outbreak of a disease in a particular geographic area, or other observable health or ecological problems, environmental scientists first determine whether environmental pollution is the cause. If so, they must identify and quantify the pollutants. In such situations, scientists often do not know exactly which pollutants to seek; many different pollutants potentially might be the cause of the observed problem. Therefore, scientists rely on detection and measurement instruments that can identify a range of different pollutants quickly.

Many of the major environmental statutes and regulations have created a demand for increasingly sensitive and powerful methods for detecting and measuring individual pollutants. For example, effective implementation of the Clean Water Act requires sophisticated capabilities to identify and measure individual toxic substances. Similar requirements are associated with the provisions of the Safe Drinking Water Act relating to maximum contaminant limits (MCLs) for different chemicals.

In addition, the explosion of activity in the environmental arena has led to the development of analytical methods that are increasingly more efficient and cost-effective. For example, the vast increase in hazardous waste cleanups has resulted in sharp increases in demand for sample analyses. Approximately 1,000 sites are included on the EPA National Priority List, and thousands more are designated by individual state environmental agencies for cleanup. The process of assessing each site, selecting and implementing appropriate responses, and performing long-term monitoring involves large amounts of detection and measurement. Site-cleanup teams often measure the concentrations of several hundred different chemical compounds as part of site cleanup activities. Thus strong demand for analytical services has led to the development of sample analysis methods that can be performed at higher volumes, at lower costs, and with reproducible results of known accuracy and precision.

Advances in health and toxicological research also have created a demand for improved detection and measurement technology. Health and toxicological researchers have identified a large number of toxic substances that create health risks at extremely low levels of concentration in the environment. In some cases, in fact, significant adverse health impacts are associated with environmental concentrations that are so low that they cannot be detected and accurately measured with current instruments and methods.

For example, the practical quantification limit for vinyl chloride in drinking water is 2 micrograms per liter. The Environmental Protection Agency (EPA) has set the MCL for vinyl chloride at that level, which corresponds to an individual lifetime cancer risk of slightly greater than 10^{-4}. A lower MCL (corresponding to a cancer risk of 10^{-6}) might be preferable to protect public health, but EPA cannot lower the MCL without the capability to detect and measure at a concentration that corresponds to that cancer risk.

Key Improvements

In the early 1970s the limitations of existing technology often impeded efforts to protect the environment. First, extensive and cumbersome sample preparation procedures were required before samples could be measured, often resulting in a loss of compounds during the process. Second, detector electronics and corresponding selectivity were relatively unsophisticated for low-level and compound-specific detection. Third, data acquisition, calculation, and management had to be performed primarily without the use of computers. Extraction of key pieces of information was difficult. Modern, computer-based tools designed specifically to help manipulate data from pollutant measurement instruments were just reaching the market. Fourth, relatively few attempts had been made to couple different analytic instruments together or to use different instruments in an integrated manner. Over the past two decades, remarkable advances have taken place in each of those areas.

Gas Chromatography-Mass Spectrometry (GC-MS)

The GC-MS is a good example of technological advances in the area of pollutant detection and measurement. In fact, the development of modern GC-MS represents the leading advancement in the detection and measurement of organic chemicals.

This technology is a marriage between two highly different analytical instruments. The first, gas chromatography (GC), provides highly resolved separation of the many organic chemicals that may be present in an environmental sample. For example, a sample of liquid drawn from a drum at a Superfund site could contain hundreds of organic compounds. GC instruments enable scientists to separate the compounds so that they can be identified individually.

After being separated by a GC, each individual organic compound can be identified unambiguously by mass spectrometry (MS). Thus GC-MS provides unmatched analytical capability for the identification and quantification of trace levels of organic compounds in complex mixtures.

A number of technological advances have made today's GC-MS instruments very powerful. They are now capable of identifying and quantifying a remarkably large number of compounds. In addition to increased sensitivity, the GC-MS instrument now can perform substantially higher volumes of analyses within a given laboratory shift. For example, 20 years ago a scientist was able to perform GC-MS analyses only on three to four samples per 8-hour shift on a single instrument. Today, scientists can routinely perform analyses at four times that volume.

The increases in the power and cost-efficiency of GC-MS analysis are partly a result of improvements in methods and procedures. Sample preparation procedures are a good example. As a first step in subjecting an environmental sample to GC-MS analysis, a scientist prepares an extract of the sample by isolating the compounds of interest and then removing the compounds that are not of interest. The latter potentially could interfere with the detection and measurement of the target chemicals by the GC-MS. Over the past two decades, the methods used to prepare samples have been improved substantially.

Improvements in the power and cost-effectiveness of GC-MS analysis have resulted from technological advances—for example, improvements in the design of the GC "columns." In brief, the GC "column" is a small-diameter tube. After a sample is prepared, a small amount of the sample extract is injected into the GC, where it is rendered into its gaseous state and then introduced into the GC column.

Over the last decade, major advances have been made in the design of the GC columns. This improved technology is especially useful to environmental analysts. For example, at some hazardous waste sites typical soil samples may contain many compounds with nearly the same chemical and physical properties, such as different types of PCBs. A modern GC allows laboratory technicians to analyze such samples more quickly, more accurately, and more cost-effectively.

Increases in the power of GC-MS also are a result of improvements in mass spectrometry (MS) technology. The MS provides the analyst with information that not only detects the quantity of different compounds present, but also identifies those compounds unambiguously.

Over the past several years, advances in electronics have improved the power of MS-detection capabilities. The library of known fragmentation patterns, or "fingerprints," now contains more than 40,000 entries. The computer software used to match the fingerprints created in the MS to the automated library of known chemical fragmentation patterns has also been improved. In addition, today's GC-MS instruments are completely automated, and computer controls allow the GC-MS operator to send reports directly to the environmental inspector who requested the analysis.

For environmental regulatory agencies, which face ever-growing requirements to detect and measure pollution discharges and ambient environmental conditions, the advances in GC-MS technology translate into many advantages. Inspectors can obtain more accurate characterizations of the organic compounds in their samples—at very low levels of concentration, and even in cases where a single sample contains many compounds that are chemically very similar in structure. In addition, results can be obtained more quickly and cost-effectively. Similar benefits are being realized by regulated sources, who, for example, often rely on GC-MS analyses as part of their self-monitoring programs.

Atomic Absorption Instruments

Atomic spectroscopy is a method for the identification and measurement of most metals and metaloids, such as cadmium, zinc, mercury, and chromium. Flame atomic absorption (AA) is the most widely used spectroscopy technique.

The past few years have seen advances in the power of the technology, and AAs now can measure many compounds and elements in the 10 parts-per-billion range, in comparison to the early 1970s when those same substances could be only measured at approximately 1 part per million. Because many metals and metaloids can be very dangerous to humans, animals, and plants even at exceedingly low concentrations, environmental agencies and regulated sources often must measure low concentrations. For example, when inspectors obtain samples of wastewater discharges from an electroplating facility, a common objective is to detect and measure the concentrations of chromium or other metals in the discharge to determine how much of the residue the facility is emitting into the sewer. When EPA, a state environmental agency, or a private company assess a hazardous waste site, inspectors need to determine whether individual samples—such as those drawn from unlabeled drums stored at the site or from soil or groundwater at the site—contain metals or metaloids.

In recent years, new AAs have been developed that employ an electrothermal device in place of a flame. For some types of analyses, flame AAs can be relatively inefficient in desolvating, vaporizing, and atomizing the sample extract, for example, in analyzing metals in oily wastes. Electrothermal AAs can detect and measure some types of metals at much lower concentrations than flame AAs, while substantially reducing the amount of time required to prepare samples.

Other advances have been made in the design of the radiation sources and the detectors. In addition, advances in electronics and computer technology have increased the power of AA spectroscopy. Technological advances have helped environmental agencies and regulated sources obtain accurate information on the presence and concentrations of metals in environmental samples in a more cost-efficient and timely way.

Inductively Coupled Plasma (ICP) Spectrometers

Another critical technological advancement has been the development of inductively coupled plasma (ICP) spectrometers, which were first available commercially in 1974. For many types of inorganic compounds, ICPs offer advantages over modern AA instruments. The principal efficiency advantage of an ICP is its ability to probe for the presence of up to 35-40 compounds in a single test, while an AA instrument typically is limited to 3-5 per test. While ICP technology is relatively expensive, over the last few years the cost has decreased steadily and, on a per sample basis, it may be comparable in cost to AA technology. As ICP technology continues to be improved, the costs of Superfund cleanups will decline, as will other environmental activities, such as compliance inspections, that require analysts to detect and measure metals and metaloids in air, water, or soil.

The ICP can detect and measure some types of compounds at even lower concentrations than AA. For some extremely dangerous metals, such as some types of dioxins, the ICP allows environmental agencies to do a better job of identifying hazards, even when they are caused by contamination at exceedingly low concentrations.

The development of ICP technology also is very promising because it offers certain types of flexibility that cannot be achieved with AA instruments. For example, an ICP can accurately detect and measure individual substances in a sample over a range of concentrations. In fact, in a single test to analyze a single sample, an ICP can simultaneously detect the presence and measure the concentrations of compounds that differ in concentration by as much as five orders of magnitude, for instance from 1 part per billion to 1 part per 10,000.

Other Advances

For the analysis of nutrients, such as nitrogen and phosphorous, technologies have been developed to allow the "segmented" and "continuous flow" injection of samples into instruments such as colorimeters. As a result, laboratory staff now can analyze a much higher volume of samples in a given time period, and instrument downtime (for example, cleaning instruments between sample runs) has been reduced substantially.

Technological advancements are projected in the following areas:

- **Identifying and quantifying a wider range of pollutants.** Even with today's advanced techniques, many types of pollutants still cannot be readily identified or measured. Refinements in technology and methods for existing instruments continue to be made.

- **Developing improved methods for analyzing specific characteristics of chemicals of concern.** Scientists need to improve methods for identifying and quantifying chemical substances in particular regions of soil, air, or water particles, such as the surface microlayers of particulates.

- **Improving cost-effectiveness.** Regulatory agencies and regulated industries both will benefit from continued progress in developing instruments and methods that will lower the costs of performing analyses while maintaining acceptable levels of sensitivity, precision, and accuracy.

  For example, progress in streamlining sample-preparation techniques and developing computer software to analyze data can improve cost-effectiveness. As another example, supercritical fluid chromatography (SFC), a measurement technology currently being developed, has the potential to increase the efficiency of GC analysis even further.

- **Improving field-based techniques.** Substantial progress may well be made in developing improved field-based detection and measurement methods. For example, sensitivity, precision, and accuracy of field-based GCs and

GC-MSs could be improved substantially in the 1990s. Field-based instruments can minimize downtime for cleanup personnel and equipment, because samples don't have to be sent off site to laboratories.

EPA, a Tufts University researcher, and a private firm offer another example. Recently the three working together used a field-based GC-MS to test supercritical fluid extraction, a new cleanup technology in removing PCBs from contaminated sediments at a Superfund site in New Bedford Harbor, Massachusetts. The team used the GC-MS to measure the amounts of PCBs in the sediments before and after treatment by the new cleanup technology. By using a field-based GC-MS to measure PCB removal, the team was able to obtain results in a matter of minutes, rather than the days that would have been needed had the samples been sent to a regular laboratory. This rapid turnaround enabled the team to make a series of adjustments to the cleanup technology and to identify optimal ways of "tuning" the technology for maximum performance.[1]

Other advances in field-based methods may come in the area of fiber optics. For example, it is conceivable that accurate, robust methods will be developed to use fiber optic probes, tipped with chemical sensors to measure subsurface contamination, thus avoiding the need to install monitoring wells. In one configuration, for example, the fiber optic probes could be coupled to a fluorescence instrument deployed in the field. That instrument would analyze data obtained from the probes and would enable field-based personnel to determine the presence of various types of contaminants in groundwater.

Pollutant Transport and Fate Modeling

Over the past 20 years, considerable effort has been invested in developing and refining environmental transport and fate models. The basic objectives of these models are to evaluate and predict the transport, transformation, and exchange of chemical

substances in and among air, water, sediments, and land. Environmental regulatory agencies, researchers, regulated sources, and others use models to support such activities as evaluating how pollutants from a particular industrial facility or hazardous waste site might travel through air, water, and soil. An understanding of transport and fate and of modeling these processes helps clarify how pollutants, through space and time, reach humans and other receptors.[2]

Applications

Since 1970 transport and fate models have supported analytical and decisionmaking objectives. For example, EPA uses models in the review process for new chemicals. Under the Toxic Substances Control Act (TSCA), manufacturers must obtain EPA permission to produce and sell most new chemicals. TSCA requires manufacturers to submit a "premanufacture notification" (PMN) to EPA; the agency then has to decide whether to grant permission for the manufacture and sale of the chemical, based primarily on an assessment of the potential risks that the chemical might pose in the environment. In making this assessment, EPA has to consider, among other factors, the potential transport and fate of the chemical. For its proposed commercial uses, how might the chemical be released into air, water, or land? If releases were to occur, how might the chemical be transported and exchanged among air, water, and land? What might be the fate of the substance, how might the chemical be transformed into new chemical substances, and what types of dangers might that pose?

For new chemicals, neither EPA nor the manufacturer will have empirical data on the transport and fate of the chemical in the environment, because the chemical will not yet be in commercial use. Accordingly, EPA often uses transport and fate models, among other techniques, to project the potential behavior of the chemical in the environment.

Transport and fate modeling also can be used to assess hazardous waste sites and to evaluate potential effectiveness of alternative cleanup approaches at the site. The people responsible for evaluating the risks posed by a potentially dangerous land-

fill—for example, government engineers or experts retained by the landfill owner—often use transport and fate models to evaluate the mobility of the waste, the rate at which the waste might leach into an aquifer next to or under the site, the speed at which the waste might move through the aquifer, and the types of chemical transformations that might occur.

In many cases, site assessors use modeling to complement or fill gaps in the monitoring data or to make long-term predictions. For example, monitoring data at Superfund sites typically are collected over a relatively short period of time, thus indicating current site conditions. But estimates of long-term conditions at the site are equally important. In some situations pollutant concentrations—in groundwater, for instance—may well remain constant over a long period of time, but often the monitoring data cannot accurately predict future concentrations.

Transport and fate models often can be useful in making such predictions. They also can help site assessors determine how to set priorities for additional data gathering. For example, after using a transport and fate model, EPA may be able to pinpoint where wastes leaching from a hazardous waste site are likely to be especially high. Thus EPA will be able to design an efficient monitoring program at the site.[3]

Transport and fate models can be used by regulatory agencies to help make siting and permitting decisions. For example, if a company is proposing to locate a new industrial facility on a particular site, regulators need to predict the movement and fate of air emissions and water discharges from the proposed facility. In addition, such modeling can aid in identifying alternative locations for the facility and in designing the facility itself.

Transport and fate modeling can help predict environmental trends related to phenomena that cannot be readily measured nor accurately recreated or simulated in a laboratory. For example, scientists at EPA use transport and fate modeling to help predict potential effects of different levels of fluorocarbons on the ozone layer.

Researchers at a national laboratory have created a system to assist managers following an accidental release of toxic chemicals. Using real time meteorological data and innovative modeling, it can rapidly predict the movement of radionuclides or toxic chemicals in the event of an accidental release from any of more than 50 federal sites linked to the system.

Environmental regulatory agencies also use transport and fate models to develop regulations and standards. The design of a regulation or standard also will have a direct effect on the pollutants produced. Transport and fate modeling can help agency staff predict the likely consequences of alternatives, especially in cases where the design of a regulation or standard is based on predictions of human or environmental exposures.

Key Developments

Over the past 20 years, there have been a variety of key developments related to transport and fate modeling:

- **Increased sophistication.** In the 1970s and 1980s researchers developed models to help environmental agencies and private industry assess problems. At that time, air dispersion models tended to focus on the movement of air pollutants over flat terrains. Today, researchers are developing models that can predict the transport of pollutants over more complex terrains, such as hills and valleys.

  For example, the Department of Energy (DOE) Atmospheric Studies in Complex Terrain (ASCOT) Program is addressing the problems of transport and diffusion of pollutants in mountainous regions of the United States.

  Researchers also have made progress in the development of accurate two-phase flow models. Among other things, such models help researchers predict the subsurface movement and dispersion of gasoline, which essentially "floats" on top of groundwater and which, in some circumstances, can flow in a direction opposite to the groundwater. Progress also has been made in the development of models that predict the transport and fate associated with episodic pollution releases. Such events can include accidental releases from ruptured high-pressure tanks at refineries; releases arising from breaks of containment mechanisms, such as landfill liners; and releases of dense materials, such as smoke from industrial fires.

■ **Applicability to a broader range of pollution sources.** Models now are better at predicting the transport and fate of pollutants from small dispersed sources such as urban runoff, which can be oil and grease from streets and parking lots that is swept into streams and rivers by heavy rain. Agricultural runoff may contain pollutants, such as pesticides that are washed from fields into rivers during rainstorms.

■ **Consideration of a more complete set of environmental settings.** Models that help describe the mechanisms by which pollutants enter into and travel along the food chain have been improved. They now can help explain how pollutants are transported from the air into soil and subsequently into food crops, how they are transformed within those crops, and how long they persist.

■ **Development of multimedia models.** More powerful multimedia models—models that examine how pollutants move among air, water, and soil—are now available. For example, models can now examine how pollutants that are initially discharged into the air can adhere onto airborne particulates and fall into lakes and rivers. Accurate multimedia models are needed, because many key environmental problems—for example, acid rain—involve movements of pollutants. In addition, environmental regulators are becoming increasingly aware of the need to avoid technological "solutions" that simply take pollutants out of one environmental medium, such as the air, and move them into another, such as groundwater, where they can pose human health or ecological risks.

■ **Increased use in the design of regulations and standards.** In recent years, modeling has been used in regulatory and standard-setting processes, such as the development of new waste characterization rules under the Resource Conservation and Recovery Act (RCRA). One example is the EPA effort to revise and expand the RCRA toxicity characteristic rule that defines wastes subject to regulations.[4]

EPA developed the "EPA Composite Model for Landfills" (EPACML) to support the rulemaking process. The model analyzes alternatives and helps shape the process by which numerical standards are set. It has become a focus of the rulemaking process. EPA published the specifications for the model in the *Federal Register* and formally solicited comments. The agency received hundreds of comments from industry and elsewhere, and the model has been revised accordingly. Revisions have led to a recasting of some proposed regulatory limits.

■ **Improved and more widely available computational tools.** The past 20 years witnessed a revolution in information technology. Transport and fate computer models now can take advantage of extraordinary advances in the availability of computing power. The speed of computation has improved considerably; the hardware has become progressively more compact and accessible; software has become more powerful; and computing costs have gone down. In addition, the easier availability of computing technology has encouraged large numbers of individuals with a variety of technical skills to become involved in model development.

■ **Increased availability of monitoring data.** Developing, testing, refining, and validating transport and fate models require actual monitoring data. Such data often are used to test a model's predictive capabilities and to adjust and refine its equations. The technology used to detect and accurately measure pollutants at relatively low levels of concentrations has evolved to such an extent that models now are capable of analyzing the transport and fate of highly toxic compounds like dioxins.

Control Technologies

Over the past 20 years, the United States has made substantial progress developing pollution control technologies that improved (1) as Congress enacted laws mandating improvements, (2) as firms decided to control pollution in response to increasing costs for residuals management and concerns about potential liabilities, and (3) as an environmental service sector developed in response to increasing opportunities.

One indication of this country's commitment to reducing pollution is the increasing amount of resources devoted to control technologies. In 1975 the United States spent about $30 billion on pollution abatement and control expenditures. By 1986 the amount had increased by about 250 percent to almost $78 billion. Even after adjusting for inflation, the increase was about 38 percent.[5] Human resources as well as money are being devoted to pollution control. For example, the number of graduate students enrolled in environmental science programs has increased by about 20 percent since 1975.[6]

Twenty years ago the environmental service sector was comprised almost entirely of small local firms that collected and disposed of solid waste and of engineering firms that designed and constructed wastewater treatment plants. Today the environmental service industry has revenues of over $30 billion per year and is growing at an annual compound rate of 15-20 percent per year.[7] Large national firms now collect and dispose of hazardous and solid wastes, generating attendant revenues of about $20 billion per year, and solid waste recycling and incineration generates revenues of about $5 billion per year.

Past waste management practices in some places resulted in contaminated landfills, impoundments, and aquifers. The estimated cost of remediating such problems has been estimated at over $200 billion. By beginning the cleanup of these problems, the hazardous waste remediation business generates revenues of over $2 billion per year. Analytical laboratories providing the testing services required under many environmental statutes generate revenues of about $1 billion per year while environmental consulting and engineering firms do about $2 billion per year in business.[8]

Electric Utility Air Pollution Control

Air pollution control technology for fossil-fueled electric utility power plants is a good example of how new methods are being applied to solve environmental problems. Improved technologies now provide reliable and proven—although in some cases very expensive—options for the control of sulfur dioxide, nitrogen oxides, and particulate emissions. Numerous systems have been back-fitted onto existing power plants. The growing complexity and cost of the systems have stimulated efforts to develop innovative technologies with inherently less emissions. In short, the electric utility industry has available the greatest number of potential control options and new generating approaches in its history.

The principal emissions control technology for sulfur dioxide is flue gas desulfurization or "scrubbing." Scrubbing removes sulfur dioxide gases via a series of chemical reactions between the sulfur dioxide gases in the power plant's flue gases and a water limestone slurry. The reactions produce a wet gypsum/water waste stream that usually is dewatered and landfilled. The reaction occurs in a large tower vessel located near the point where the flue gas enters the plant's smokestack. The flue gas is diverted to the tower where the water limestone slurry is dropped onto it, "scrubbing" away up to 90 percent or more of the sulfur dioxide. Thereafter, the flue gases are sent to the stack, and the sulfur wastes are removed from the bottom of the stack in a wet state.

In the 1960s utility scrubbers had not yet been demonstrated with the reliability and performance needed by the electric utility industry. In the 1970s scrubbers emerged from the pilot and small-scale testing stage to full-scale commercial application, but the first generation of systems experienced reliability and performance problems.

Twenty percent of the coal-fired utility power plant capacity in the United States currently treats flue gas with scrubbers. Today all new utility coal-fired power plants have scrubbers that operate reliably; they remove up to 95 percent or more of the sulfur dioxide in flue gases. In part, because of scrubbers, emissions of sulfur oxides from electric coal-fired utilities have declined by

about 10 percent over the last two decades,[9] while total power generated from these utilities has almost doubled. Although scrubbers are an effective method of removing sulfur dioxide, their primary drawbacks are high cost, the need for greater electricity generation to operate them, and sludge disposal. Consequently, the DOE Clean Coal Program is helping to develop new pollution control technologies with the potential to remove sulfur dioxide more efficiently and economically.

The principal nitrogen oxide control technologies in use today in the United States are relatively inexpensive modifications of furnace and combustion systems. Modifying the systems can reduce nitrogen oxide formation by approximately 40-60 percent. Relative to the 1960s, combustion modifications have improved significantly. Nitrogen oxide scrubbing, which has the potential for reductions of up to 90 percent, has emerged recently as a possible control option for electric utility power plants. In the last three years, nitrogen oxide scrubbers have been installed at some new U.S. oil-and natural gas-fired utility power plants. Such scrubbers are being tested for the first time on coal-fired power plants in the United States, and they have been used at coal-fired plants in Europe and Japan. However, the high cost of nitrogen oxide scrubbers deters their widespread use in the United States.

Particulate emissions control technology is more mature, efficient, and widely used than controls for either sulfur dioxide or nitrogen oxides. For decades most coal-fired power plants have been built with mechanical collectors that controlled about 40-60 percent of a plant's particulate emissions. Over the last 20 years, all power plants have added more efficient control systems, such as electrostatic precipitators and fabric filters, that remove up to 99.9 percent of a plant's emissions. Because of such control systems, total particulate emissions from electric utilities have declined by about one-sixth from 1970 to 1986.[10]

In the past decade, the cumulative effects of the back-fitting of complex and costly control systems, each designed for an individual pollutant, have contributed to the development of integrated technologies, such as:

- Fluidized Bed Combustion (FBC) boilers control both nitrogen oxide and sulfur dioxide formation in the boiler furnace.

- Integrated Gasification Combined Cycles (IGCC) convert coal to natural gas, after which the sulfur and particulate matter is removed. Nitrogen oxide formation is reduced relative to conventional coal-fired power plants, since the gas is burned in a turbine.

Automobile Air Pollution Control

Spurred by the enactment of the Clean Air Act Amendments of 1970, which set emissions standards for automobiles beginning with the 1973 models, manufacturers have developed and deployed technologies that have led to substantial declines in emissions from passenger cars. Between the 1960s and the late 1980s, emissions of hydrocarbons and carbon monoxide have declined by about 96 percent per mile traveled; total transportation hydrocarbons were cut in half even though vehicle travel nearly doubled during the same period; nitrogen oxide emissions declined by about 76 percent per mile traveled.[11] Finally, and perhaps most significantly for the environment, engines have been developed that are not dependent on tetraethyl lead as a fuel additive. As a result, lead emission from vehicles has decreased by almost 99 percent in the past two decades.

Air pollution control devices for automobiles are designed to eliminate the chemical compounds that escape from the engine crankcase, from the exhaust, and from evaporation of fuel from the fuel tank and carburetor. Today, with the growing use of on-board computers, car manufacturers can help meet federal emissions standards by using electronic engine controls to monitor operating conditions and adjust engine calibrations for the best possible performance and economy.

In 1963 automobile manufacturers introduced the first component of today's control system: the positive crankcase ventilation (PCV) system. Exhaust gases that escape past the piston rings into the crankcase are prevented from escaping into the atmosphere by the PCV system, which draws the gases into the engine and burns them. Thus the PVC system reduces the emission of volatile organics (VOCs) from automobiles.

In 1971 the first engines designed to burn unleaded fuels were introduced. Those engines gained increasing market penetration, and today all newly manufactured engines burn lead-free gasoline.

In 1974 automobile manufacturers introduced catalytic converters, which limit emissions of NO_x, VOCs, and carbon monoxide. Two main types of catalytic converters are typically used. The first is an oxidation-type converter that uses platinum and palladium to facilitate the combustion of hydrocarbons (HC) and carbon monoxide (CO) emissions. Oxidation converters do not operate unless sufficient oxygen is in the exhaust stream. The necessary oxygen is provided by either an air pump system or a pulse air-type system. The second type of converter is a three-way catalyst, which contains platinum and rhodium in the front part of the converter to reduce NO_x emissions, while platinum and palladium are used in the rear section to oxidize the hydrocarbons and carbon monoxide.

Hazardous Waste Control and Remediation

Control and remediation technologies for hazardous waste have been improved substantially over the past 20 years. In 1970 solid and semisolid wastes that now would be classified as hazardous wastes were usually placed in unlined landfills, while liquid wastes were placed in impoundments, and neither landfills nor impoundments were sited to minimize environmental effects. Those facilities did not collect leachate, and they did not monitor the groundwater to detect leakage. After the useful life of the facility, owners often walked away without a proper closing.

Today's land disposal facilities are much improved. Wastes are not just dumped in the ground; they are placed into facilities with synthetic liners that hold wastes inside the facility and with leachate collection systems that keep hydraulic pressure from building and rupturing the liners. Such facilities also monitor groundwater to detect leaks. Finally, because of EPA regulations, many wastes now are treated prior to their emplacement in land disposal facilities to limit the mobility of the waste and reduce its toxicity.

Not only is land disposal safer, but treatment alternatives have been developed that change the character of waste to render it less hazardous or nonhazardous, or that reduce the volume of the waste. Incineration is one such form of treatment. It is a thermal process primarily used to burn organic liquids and sludges. Modern incinerators can remove or destroy over 99.99 percent of the principal hazardous organic constituents of a waste stream. Other treatment technologies, like neutralization to adjust the pH of a waste, precipitation to remove heavy metals, and stabilization to prevent hazardous constituents from leaching out, also are used widely.

Although modern waste management technologies are comparatively nonpolluting, past practices left a legacy of contamination to be remediated. Fortunately, progress in developing remediation technologies has been considerable. In 1970, because few people understood that groundwater could be contaminated, little attempt was made to clean it. Today well-established methods are used to delineate the extent of contaminated groundwater plumes, determine the optimal number and configuration of withdrawal wells, and treat the contaminated groundwater to remove pollutants.

Methods for controlling the source of the groundwater contamination also have improved. In the early days of Superfund, pollution control at a Superfund site usually was limited to capping the soil—covering it with a clay cover to limit infiltration of rainwater and thus reduce leaching from the soil into the groundwater. Unfortunately, capping was not a permanent remedy; it did little to reduce the toxicity or the mobility of the waste stream.

Remediation managers can now select from technologies like solvent extraction, solvent washing, biological degradation, in-situ vitrification, soils washing, liquid/solid contact digestion, in-situ stabilization, and ultraviolet/oxidation treatment for liquids.

Research and Development: Directions and Funding

In the field of research and development (R&D), public agencies are working with private firms, and nations are working together to improve technological capabilities.

Public and Private Sector Partnerships

To fully address environmental problems, all sectors of the economy—including the private sector, academia, and government—need to research and develop innovative pollution control technologies. In many cases, partnerships among the different sectors achieve innovations. When the modern environmental movement began 20 years ago, few mechanisms existed to encourage or facilitate such partnerships. By 1989 that situation had changed.

Joint Laboratory-Based Research

The Federal Technology Transfer Act (FTTA) enacted in 1986, created substantial new authorities and opportunities to help pollution control agencies, such as EPA, work collaboratively with the private sector. The law authorizes federal agencies to enter into cooperative ventures with private industry, universities, and others to research, develop, and commercialize new pollution control technologies.[12] The mechanisms for encouraging collaboration include:

- **Resource sharing.** Under the FTTA, federal agencies such as EPA can accept funds, services, and property from collaborating parties, such as private firms, within the terms of the cooperative venture. For example, private firms engaged in a research project with EPA can provide funds or staff to the agency. EPA also is authorized to provide resources (but not funds) to collaborating parties to

help develop or commercialize a new technology of benefit to the environment. Under this authority, for example, EPA scientists can work in the laboratories of a private firm.

■ **Licensing agreements.** The FTTA enables EPA to grant, in advance, licenses to patents on inventions made by federal employees as part of a collaborative effort. In addition, the law allows EPA to negotiate and issue patent licenses on inventions the government owns, which is useful, for example, when a private firm interested in an existing invention wants to develop it further.

■ **Royalties.** In some cases, the licensing agreement can provide for an exclusive license to use government-owned inventions and for royalties to be paid by the licensee. In those cases, the law provides for such royalties to be paid to the participating agency, and at least 50 percent of those royalties must be allocated to the participating laboratory or division. In addition, the law requires a direct payment of at least 15 percent of the royalties directly to the government employee-inventor(s) up to a limit of $100,000 per employee per year. Within EPA, the percentage of the royalties allocated to the employee-inventor(s) is 35 percent, and the remaining 65 percent of the royalties go to the laboratory or division.[13]

In the short time since the FTTA has been in place, EPA has initiated six collaborative projects, and another 10-15 are being negotiated. EPA collaborative efforts currently underway or being negotiated cover a range of functional areas, such as field-based monitoring instrumentation, biotechnology, and commercialization of a state-of-the-art atmospheric test chamber. For example, a Swedish firm is paying EPA $50,000 per year to help fund work being performed in the EPA Air and Energy Research Laboratory in Research Triangle Park, North Carolina. The laboratory is working to improve pollution control technologies for power plants. If successfully developed, the technologies will be used in conjunction with the Swedish firm's existing pollution control equipment, currently in place in many power plants.[14]

The EPA Gulf Breeze Environmental Research Laboratory is working in cooperation with a private U.S. firm that is developing a new microorganism to biodegrade chemicals such as creosotes and some types of organic contaminants. The company is small and lacks the equipment and personnel to support field-testing and other developmental procedures. Consequently, it is paying the EPA Gulf Breeze Laboratory $70,000 to evaluate and field-test a new, less expensive technology to clean up contaminated water and soils.

EPA also is working cooperatively with a New Mexico firm to develop a new field-based detection technology based on fiber optics. Fiber optic probes, tipped with sensors that fluoresce in the presence of specific chemicals, can detect the presence of selected pollutants beneath the ground without the use of expensive monitoring wells. The firm has substantial expertise in fiber optics technology, but it needed EPA expertise in developing chemical sensors and using fiber optics in environmental applications. The agency has assigned a staff scientist to work in the EPA Las Vegas Environmental Monitoring Systems Laboratory, and the company reimburses EPA for the scientist's salary.

Technology Innovation in Superfund

In the first several years of the Superfund program, EPA encountered difficulties encouraging the development of innovative cleanup technologies. Private sector technology developers also faced obstacles in trying to introduce new technologies into the Superfund cleanup process.

EPA decisionmakers for Superfund sites tend to select cleanup technologies that have been tested fully. To develop sufficient data, a company needs actual field conditions to test a new technology, and the only place to do that is at a Superfund site.

To help address this problem, the Superfund Innovative Technology Evaluation (SITE) Program was established in 1986, as mandated by the Superfund Amendments and Reauthorization Act (SARA). The purpose of SITE is to accelerate the development and use of innovative cleanup technologies at hazardous waste sites.

SITE Emerging Technologies Program

Under the Emerging Technologies portion of the SITE Program, EPA has entered into cooperative agreements with developers of promising new technologies, including private sector technology companies and public or private universities. EPA and the developer test the technologies under controlled conditions. EPA provides the testing protocols and shares in the cost of the testing, providing up to $150,000 per year for two years or up to 70 percent of the cost of the testing program.[15]

In 1989 the Emerging Technologies Program tested 14 new technologies and considered 17 others.[16] The program already has yielded results. One example being developed by another New Mexico company uses biological processes to remove metals like lead, mercury, cadmium, and chromium from groundwater and surface water. The technology can be used by cleanup teams at hazardous waste sites, and by electroplating, metal finishing, and printed circuit board manufacturing industrial facilities to treat rinse waters.

Heavy metals can be removed from water by passing the liquid through a silica gel polymer. Certain types of metals have a natural affinity to be absorbed out of the water and to attach to the surface of the polymer particles, where they are immobilized.

The firm developed the process and then requested that EPA help test and prepare it for commercialization. EPA consequently funded a large portion of the costs of testing the process on mercury-contaminated groundwater at a hazardous waste site in Oakland, California, in the fall of 1989. The results of the test were encouraging, and the technology is being commercialized.

In some situations, the process may be less costly than other processes for treating metal-contaminated liquids. If so, it can help reduce costs of Superfund cleanups and provide industrial facilities a cost-effective means of treating rinse waters. In contrast to most other biological recovery systems, the new process is efficient in removing heavy metals from "hard" water.[17]

Another promising new technology is a wetlands-based treatment process for removing metals from acidic drainage from metal and coal mines. Acidic mine drainage, a type of liquid waste that typically contains high metal concentrations, is acidic in nature. Such waste often drains into wetlands near mines and

contaminates surface streams used for drinking water. A wetlands-based treatment process being developed by the Colorado School of Mines is based on a microbial process that operates in the soil beneath contaminated wetlands.

Tests performed to date by EPA and the Colorado School of Mines under the SITE Emerging Technologies Program have been encouraging. A pilot-scale system has been built to assess the effectiveness of technology in treating effluent from the Big Five Tunnel, a mine near Idaho Springs, Colorado, from which substantial amounts of acid mine drainage have contaminated drinking water supplies. Tests indicated that the technology promises substantial reductions in acidity; initial results showed an ability to raise pH from 2.9 to 6.5. Zinc, cadmium, aluminum, and lead contamination may be reduced by 90-100 percent, and copper contamination may be reduced below measurable levels. The treatment also may reduce the costs of cleaning up sites contaminated with acid mine drainage. Preliminary data suggest that the costs of using the technology could be as low as 20 percent of current costs.[18]

The Department of the Interior (DOI) Bureau of Mines has a research program in which wetlands are constructed for the purpose of treating acid mine drainage. The wetlands provide a low-cost, low-maintenance biological treatment as an alternative to costly conventional chemical treatments. More than 300 of the new wetlands are now in use. Research focuses on wetlands treatment mechanisms, long-term wetlands performance, optimum wetlands design criteria, and biological treatment processes.

Another example is the "solvent washing" process being developed by an Alabama firm. Solvent washing is a method of cleaning soils contaminated with certain types of organic compounds such as PCBs and dioxins. The process is analogous to dry-cleaning clothing. A large "contactor" is used to mix contaminated soils with a solvent. The mixture is agitated, usually for an hour, and the organic contaminants are drawn out of the soil and dissolved in the solvent. The solvent containing the dissolved organic contaminants is then drawn off and separated from the soil.[19] The solvent from each wash is delivered to a reclamation system, where it is distilled. As a result of distillation, the organic contaminants are concentrated into a heavy

sludge, or "still bottom." The still bottom can be further treated off or on site depending on economics and other considerations.

Solvent washing offers several advantages for hazardous waste site cleanups. Liquid discharges are limited to non-contact cooling water (that is, water used for cooling purposes that does not have any contact with solvents or soil), and water that is initially present in the soil. When the latter is discharged, it is clean and typically does not require additional treatment before being released back into the environment.

Unlike high-temperature processes such as incineration, solvent washing does not alter the basic structure of the soil. Consequently, cleaned soil is suitable for sustaining vegetation. In addition, the solvent washing equipment is mobile (which can result in substantial cost-savings for site cleanups), operates at low temperatures (which reduces hazards to workers at the site), is totally enclosed (producing virtually no air emissions), and generates few residual wastes. Accordingly, this technology holds substantial promise for helping simplify and reduce the costs of cleanups of hazardous waste sites contaminated with PCBs, dioxins, and other organic compounds.[20]

SITE Demonstration Program

After initial results are evaluated under the Emerging Technologies Program, a new technology is ready for a field demonstration. Through the SITE Demonstration Program, EPA selects sites at which the technology will be tested and gives the developer access to the site. Demonstrations are conducted at hazardous waste sites, usually Superfund sites, or under conditions that closely simulate actual wastes and conditions, to assure the accuracy and reliability of the information collected.

Developers are responsible for transporting the equipment to the site, operating the equipment on site during the demonstration, and removing the equipment from the site. EPA is responsible for project planning, sampling, analysis, quality assurance, quality control, preparing reports, and disseminating the results of the tests. If the developer is unable to obtain financing elsewhere, EPA may consider bearing a greater portion of the total project cost.[21]

To encourage general use of successful technologies, EPA prepares a series of reports that document results from the field tests. The agency also evaluates all available information on the specific technology and analyzes its applicability to different types of sites. Those reports are published and distributed to the user community to provide reliable technical data for Superfund decisionmaking and to promote the technology's commercial use.

At present there are 37 active participants in the demonstration program. To date, 14 technology demonstrations have been completed, several reports have been published, and others are in various stages of production.[22]

While this relatively new program has encountered some startup problems, it too has yielded results. For example, an infrared thermal destruction system was tested and evaluated. The infrared unit uses an electric-powered, infrared heat source instead of fossil fuels, which results in lower fuel use and a smaller emissions control system. Particulate emissions also are reduced because the soil is processed virtually undisturbed on the primary combustion conveyor belt.

Under the SITE program, demonstrations and evaluations were conducted at two sites, using a pilot-scale unit at one and a commercial-scale unit at the other. Based on those data and data obtained from other applications of the technology, EPA was able to assess the technology's suitability for cleaning up the types of materials found at the test sites and its potential effectiveness in cleanups of other types of sites and materials. For example, EPA concluded that this technology was suitable for cleaning soils or sediments with organic contaminants over a specific range of physical characteristics.[23]

Improved Leak Detection Technology

In addition to programs, such as SITE, that help develop and test a range of technologies, private and public sector collaboration in the late 1980s helped develop and transfer technology to meet specific environmental needs. An example is the program that a group of EPA scientists recently initiated, in collaboration with private sector firms, to help accelerate the development of accurate technologies and methods for determining whether underground storage tanks are leaking. As a result of the program,

EPA and private sector vendors of testing services have developed better ways of detecting leaks in underground tanks.

In recent years, the increase in leaks from underground storage tanks containing fuel and other hazardous materials has had a significant adverse impact on the environment. Such leaks can cause substantial damage to underground sources of drinking water. From 1.5 million to 3.5 million storage tanks exist in the United States, and as many as 15 percent may have some leakage already. Up to another 10 percent may develop leaks within the next five years.

Leakage of hazardous materials from underground storage can degrade the environment, endanger human health, and require expensive cleanup procedures. To prevent, reduce, or avoid such problems, regulatory agencies and tank owners must have accurate methods to detect leaks. Inaccurate methods can lead agencies or tank owners to mistakenly conclude that a tank is not leaking, when in fact it is polluting groundwater supplies. Inaccurate methods also can cause agencies or tank owners to mistakenly conclude that a sound tank is leaking, thus causing substantial unnecessary expense, including the cost of digging up tanks and the income lost while the tanks are out of service.

The enactment of the Hazardous and Solid Waste Act (HSWA) amendments to RCRA (1988) established the underground storage tank (UST) program. Under HSWA, a large number of owners were required to test their underground tanks for leakage. EPA was responsibile for promulgating regulations and standards and establishing performance requirements for leak testing. EPA wanted to ensure that, when complying with leak-testing requirements, tank owners and operators could measure leaks accurately.

EPA met with a number of the 25 major vendors of internal volumetric leak detection testing services. Many of the vendors claimed an ability to detect leaks as small as .05 gallons per hour, but virtually no test data existed to verify the claims. Since the vendors had not conducted rigorous testing, EPA proceeded to establish performance standards for testing.[24]

The Risk Reduction Engineering Laboratory in the EPA Office of Research and Development designed and constructed a full-scale testing facility in Edison, New Jersey, and performed a comprehensive set of tests to evaluate the accuracy and precision

of each vendor's detection equipment and methods. The cooperative efforts of EPA and the vendors led to technological advances, particularly in-tank leak detection.[25]

In 1989 the capability of regulatory agencies and tank owners to identify leaking tanks was vastly more accurate than 20 years ago, or even 5 years ago. As a result, the public is better protected, because leaks can be detected more easily and more accurately.

International Technology Transfer and Cooperation

International technology transfer and cooperation facilitates environmental research and development. International cooperation is being promoted because environmental problems are not limited to national boundaries, and because technical expertise can be found throughout the international community. U.S. efforts in international technology transfer and R&D involve the government, academia, the private sector, and other nongovernmental entities.

Environmental Protection Agency

Since the founding of EPA, that agency's mission has included support of technology transfer with other countries and promotion of cooperative R&D. Even before the creation of EPA, the National Environmental Policy Act of 1969 directed federal agencies to "recognize the worldwide and long-range character of environmental problems and, where consistent with the foreign policy of the United States, lend support to the initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind's world environment." In addition, many of the statutes administered by EPA contain international mandates. For example, the Clean Water Act mandates cooperation with Mexico and Canada, and sections of the Clean Air Act are directed at limiting transboundary air pollution and encouraging international cooperation on the protection of the ozone layer.

International technology transfer and cooperation can benefit R&D in a number of ways:

- **Provide direct benefits to EPA domestic programs.** In some cases, research being performed by U.S. scientists or EPA regulatory development can be strengthened and enriched by the research results of experts in other countries. For example, EPA has benefited from information from the Organization for Economic Cooperation and Development (OECD) on chemicals and pollutants that EPA regulates or may regulate.

- **Identify pollution control technologies developed in other countries that might be applied in the United States.** For example, progress in developing certain types of flue gas desulfurization technologies for coal-fired electric power plants has been made in other countries, and the DOE Clean Coal Program is evaluating a selective catalytic reduction process developed in Japan. Innovative waste cleanup technologies, such as improved methods for treating asbestos wastes found at hazardous waste sites, have been developed in the Federal Republic of Germany. While it cannot become directly involved in financing or purchasing foreign technologies, the agency can help introduce efficient technologies into the U.S. market.

  Another example is the internationally-developed technologies deployed in the response to the *Exxon Valdez* oil spill. EPA, the Coast Guard, NOAA, and Exxon consulted with experts from the Canadian federal environmental agency for advice on cleanup methods. Skimmer equipment developed in Europe was found to be helpful in removing oil from near-shore waters. Exxon used a bioremediation technique developed by American and French scientists on some oil-soaked beaches; both American and French fertilizers were used to stimulate rapid growth of the "oil-eating" microorganisms. As part of its response, Exxon obtained equipment from a stockpile maintained in Southampton, England, by a cooperative funded by several oil companies.[26]

■ **Contribute directly to solving bilateral environmental problems that affect the United States and its immediate neighbors.** For example, technology transfer and cooperation on R&D are major factors in the Great Lakes Water Quality Agreement between the United States and Canada, and in bilateral efforts to resolve water and air pollution issues along the U.S.-Mexican border.

■ **Contribute to meeting the environmental goals of other countries.** In cooperation with the U.S. Agency for International Development, EPA is helping to establish an improved air monitoring network in Poland. Besides supplying advanced monitoring equipment and analytic technology for the network, EPA is training Polish government staff to operate and maintain the technology. In addition, EPA is helping to develop a new "East-West" regional environmental center in Budapest, Hungary, that will focus, in part, on technology transfer and cooperative R&D. Such efforts directly support the Administration's foreign policy goals related to Eastern Europe.[27]

In performing its international technology transfer and cooperative R&D activities, EPA works with a variety of international and environmental organizations. They include organizations within the United Nations, such as the World Health Organization, the Food and Agriculture Organization, and the U.N. Industrial Development Organization. EPA also works with multilateral development banks such as the World Bank.

Bilateral Agreements

EPA participates in a number of bilateral agreements, some of which have been in place since the early 1970s. These range from broad government-to-government science and technology cooperation agreements to agency-to-agency Memoranda of Agreement or letter agreements. (For a more complete discussion of bilateral environmental agreements, see Chapter 7 of this report: International Issues.)

For some of the broad government-to-government agreements, EPA is the lead administering agency for the United States. For others, this responsibility is assigned to other offices, such as the Office of Science and Technology Policy (OSTP) within the White House.

The agreement with the Soviet Union, for which EPA is the lead U.S. agency, provides a good example of how cooperative R&D can be beneficial, especially in light of global environmental issues. Researchers in the Soviet Union and the United States have established more than three dozen joint research projects on environmental topics under the auspices of the Agreement on Cooperation in the Field of Environment.[28] A number of public and private institutions participate in research projects, and universities, such as Bowling Green State University, lead research projects. Other U.S. participants include the USDA/ Forest Service, foundations that have lent financial support for U.S. participation, such as the Edward Lamb Foundation, individual companies such as B.P. America, and industry groups such as the Electric Power Research Institute (EPRI).

For the Soviet Union, the agreement is administered by the Goscompreroda, the State Committee for Nature Protection. A number of institutes in the Soviet Academy of Sciences also participate.[29]

One such project under the U.S.-Soviet agreement is entitled Air Pollution Effects on Vegetation Including Forest Ecosystems. Much of the work is directly relevant to studies of international pollution problems like global climate change. In addition to providing a mechanism for sharing expertise, that joint research project has enabled the participating scientists to study a wider range of vegetation, in a wider range of settings, than otherwise would be possible. In 1989 the researchers published the proceedings of a joint symposium. Five of the participating Soviet scientists performed research in the United States and seven of the participating U.S. researchers performed research in the Soviet Union.

The following are examples of U.S.-Soviet research:[30]

- **Physiological investigations.** A number of American and Soviet physiologists are cooperating in studies that investigate the mechanisms by which pollutants affect plants and the degree to which pollutants retard physio-

logical processes such as photosynthesis. One such study involves attempts to ascertain the photosynthetic responses of tree seedlings to pollutant stress when they are grown in an atmosphere enriched with carbon dioxide. That work is especially relevant to current concerns about global climate change.

■ **Tree ring research.** The study of tree rings—the domains of dendroecology and dendrochronology—holds immense promise for research on the effects of pollution stresses on vegetation. Correlating variations in tree rings with emissions of environmental pollutants, such as sulfur dioxide, can provide major insights into the vegetative effects of different levels of industrial pollutants. Until recently, however, American scientists were faced with a major data gap; they had almost no access to Soviet tree ring data. Three years ago the United States entered into a joint research project with the Soviets on tree ring research. U.S. participation is led by scientists in the University of Arizona's Tree Ring Research Laboratory, and Soviet participation is led by scientists at the Institute of Plant and Animal Research of the Ural Division of the Soviet Academy of Sciences.

Joint research has provided U.S. scientists with access to a vast amount of new tree ring data. In addition, scientists with similar interests in both countries now have mechanisms for communication and peer review essential to international progress in environmental research.

■ **Bioindicators.** Certain types of plant species are indicators of environmental stress. For example, lichens are good indicators of stress from several types of airborne pollution. The Soviets have made progress in identifying and testing the sensitivity of bioindicators. This research is of interest to the United States for its potential application in ecological risk assessment. In the 1980s U.S. and Soviet researchers recognized that increased cooperation and sharing of research results could help accelerate advances. Under the auspices of the U.S.-Soviet Environmental Protection Agreement, researchers from the Soviet

Union and several U.S. institutions, such as Oak Ridge National Laboratory, Arizona State University, and Ohio State University, are collaborating on bioindicators research.

■ **Atmospheric deposition gradient studies.** EPA and the Forest Service have jointly established the Forest Response Program to study the real-world impacts of sulfur deposition on vegetation. To obtain statistically meaningful and robust results, they are studying atmospheric deposition gradients, ranging from pristine areas to areas that are heavily polluted by sulfur dioxide. The Soviets also have an interest in sulfur dioxide deposition impacts on vegetation. Under the U.S.-Soviet Environmental Protection Agreement, U.S. and Soviet researchers are coordinating research.[31] The Soviets are establishing a project laboratory, and they have agreed to a major data collection effort. U.S. protocols and data quality assurance procedures will ensure that data can be compared.

■ **Anatomical studies.** The University of Illinois Center for Electron Microscopy and the Komarov Botanical Garden (Leningrad), the largest and most prestigious botanical laboratory in the Soviet Union, are studying the effects of pollutants on organisms at the subcellular level. Such investigations can aid in understanding the fundamental mechanisms by which pollutants injure plants.

International Environmental Technology Transfer Advisory Board

In 1989 at the direction of the President, EPA formed an advisory group to find ways to improve the transfer of U.S. environmental technology to other countries. That group, the International Environmental Technology Transfer Advisory Board (IETTAB),[32] is counseling EPA and other concerned agencies on the transfer of environmental technology and information to developing countries. Many developing countries need assistance in using environmental technology effectively.

The Advisory Board is providing the following assessments:

- Environmental technologies needed by developing and centrally planned countries;
- Legal and institutional barriers to the transfer of environmental technology to such countries;
- Economic barriers to the transfer of environmental technology to countries like Poland and Hungary; and
- Needs for assistance in developing appropriate environmental technology for such countries.

The approximately 15 members of the board represent industry and business; academic, educational, and training institutions; government agencies; international organizations; environmental groups; and non-profit entities. The board will focus initially on the transfer of technologies required by low-income countries with regard to ozone depletion and global warming.

Center for Hazardous Materials Research

Many technology transfer initiatives are spearheaded by non-government organizations. One example is the Center for Hazardous Materials Research (CHMR), established in 1985 as a not-for-profit subsidiary of the University of Pittsburgh Trust. CHMR is active in international research and technology transfer programs designed to introduce environmental control technologies developed elsewhere in the world into the U.S. market. CHMR initiatives are funded by public and private sources.

Examples of CHMR efforts in international technology transfer include:

- **A cooperative venture to develop new soil washing technology currently used in Holland.** A soil washing system has been successfully applied in Holland by The Netherlands Organization for Applied Scientific Research (TNO) and a private firm. The system has been successfully used for removing organic chemical contaminants from soils, sludges, and ash, but it has not been

fully developed for effective removal of heavy metals, such as mercury or chromium. A heavy metal application, if successfully developed, might be of use in the United States. If cost-effective, it could help reduce cleanup costs at Superfund sites. The process also is designed to be used on site, thus simplifying the logistics of cleanups.

■ **A CHMR international consortium of public and private entities to help develop a heavy metal removal system.** The project will be jointly financed by CHMR, EPA (under the agency's Emerging Technologies Program), a private Dutch firm, and TNO.[33]

■ **Development and commercialization of a West German technology for treatment of asbestos waste.** The most common practice for disposing of asbestos waste is to bag and landfill it. This practice creates potential risks, should operational problems occur at the landfill. To eliminate the possibility of future problems, the properties of the asbestos fibers must be destroyed. One potential method is "vitrification," a process whereby the asbestos material is converted in a glass furnace to an asbestos-free, glass-like material that is chemically and thermally stable and resistant to leaching.

A private company in the Federal Republic of Germany has been applying glass furnace technology to environmental problems since the early 1980s. The process has been used to vitrify high-level radioactive waste from reprocessed uranium fuels from European nuclear power reactors.

The Center for Hazardous Materials Research is working with a German firm to test vitrification of asbestos waste to meet environmental and worker protection standards established by the EPA and the Occupational Safety and Health Administration (OSHA). The German firm has contracted with CHMR and TNO to perform a pilot plant test in accordance with a protocol reviewed by the EPA Office of Air Quality Planning and Standards. CHMR and TNO independently concluded that the process was capable of safely converting many types of asbestos-containing waste material into asbestos-free material.[34]

■ **Drawing on European data and experience to help assess an oil spill on a U.S. river.** In 1986 a rupture in oil tanks owned by the Ashland Oil Company resulted in a large release of diesel oil into the Monongahela and Ohio Rivers. As part of its response, Ashland contracted with CHMR to conduct an independent study of the short- and long-term health and environmental impacts resulting from the spill, such as the effects on surface water and groundwater quality and on fish and waterfowl.

In conducting the study, CHMR drew heavily on the expertise and resources of TNO, which has expertise in the ecological effects of oil spills. TNO has studied Rotterdam Harbor, the largest harbor in the world, which has suffered from oil spills because of its proximity to the North Sea. The Dutch also performed intensive studies of a major toxic chemical spill in the Rhine River in 1986.

In assessing the effects of the Ashland Oil spill, Dutch scientists helped determine the significance of different types of data, such as measurements of oil concentrations in fish organs and tissue. They compared Ashland data to much larger sets of similar data obtained from the Rotterdam Harbor and Rhine River studies.[35]

World Environment Center

The World Environment Center (WEC) is another example of a nongovernmental entity that is active in international technology transfer. A non-profit, non-advocacy organization based in New York, WEC has fostered cooperation among government, industry, and academia in transferring international environmental technology, especially to developing countries. WEC projects include training internships and tours, factory and institutional assessments, institution-strengthening programs, information dissemination, and technical workshops.

Travel and management costs of WEC projects are funded primarily through a cooperative agreement with the U.S. AID Bureau for Asia and the Near East. Other funding, on a project-by-project basis, has been provided by EPA, the World Bank, the U.S. Trade Development Program, and a variety of U.S.,

Canadian, and European companies. Projects generally consist of in-kind donations of consultant services and other resources from industry, academia, and government. WEC technology transfer projects include:

■ **Hazardous waste workshops in Indonesia.** In cooperation with Indonesia's Ministry of Population and Environment, WEC held a workshop that presented hazardous waste management and waste minimization information to help industrial firms comply with the Ministry's recent hazardous waste regulatory initiative. The workshop was led by EPA staff, as well as by experts from the private sector, several academic institutions, and the Thai Office of the National Environment Board. Workshop instructors donated their time; direct costs were funded by U.S. AID and EPA.

■ **Environmental information management systems study tour.** For officials of environmental agencies in southeast Asia, WEC coordinated a 5-week study tour to familiarize them with North American organizations and systems that manage environmental information. The lack of access to information often is cited as an impediment to more effective environmental management in developing countries. Visits were made to more than 20 organizations, including the Chemical Manufacturers Association, EPA, the World Bank, the National Technical Information Service, and a variety of private sector organizations.

■ **Assessments of the tanning industries in Thailand and Turkey.** For a project sponsored by WEC, two experts from U.S. firms donated their time to perform an environmental assessment of the leather tanning industry in the Bangkok area. After performing the assessment, the experts met with representatives of the tanning and chemical industries and the Thailand environmental agency. The U.S. experts recommended alternative technical approaches to achieve improved water pollution control.

Notes and References

1. See, for example, Robbat, Jr., A., and G. Xyrafas, "Evaluation of a field-based, mobile, gas chromatograph-mass spectrometer for the identification and quantification of volatile organic compounds on EPA's Hazardous Substance List," *Proceedings of the First International Symposium on Field Screening Methods for Hazardous Waste Site Investigations*, October 11-13, 1988, Las Vegas, Nevada. EPA, Washington, DC (1989).

2. See, for example, U.S. Environmental Protection Agency, *Selection Criteria for Mathematical Models Used in Exposure Assessments: Surface Water Models*. EPA/600/8-87/042, EPA, Washington, DC (July 1987). Also see EPA Science Advisory Board, "Appendix A: Strategies for sources, transport and fate research," in *Future Risk: Research Strategies for the 1990s*, SAB-EC-88-040A, EPA, Washington, DC (September 1988). In addition to the types of modeling discussed in the text of this chapter, other types are used in developing exposure estimates (for example, modeling of human intake and human activity patterns). See, Anderson, E.L., "Perspectives on Risk Assessment," pages 281-294 in *Banbury Report 31; Carcinogen Risk Assessment: New Directions in the Qualitative and Quantitative Aspects* (1988).

3. U.S. Environmental Protection Agency, *Risk Assessment Guidance for Superfund: Volume I* -- Human Health Evaluation Manual (Part A), EPA 540/1-89/002, EPA, Washington, DC (December 1989), pages 6-25.

4. Under RCRA, a waste can be considered "hazardous" in two ways, thereby subjecting handlers of that waste to RCRA regulatory requirements: first, EPA lists specific wastes as being "hazardous"; and second, any waste that exhibits "toxicity," "reactivity," "corrosivity," or "ignitability" is considered hazardous. EPA has developed tests, procedures, and guidelines that handlers can use to determine whether any of their wastes exhibit these characteristics.

   For determining whether certain wastes exhibit the "toxicity" characteristic, generators must use an EPA-approved method for measuring the concentrations of certain constituents in the waste leachate. If the measured concentrations meet or exceed an EPA-defined regulatory limit, then, by definition, the waste stream is considered to exhibit the "toxicity" characteristic and to be "hazardous" for RCRA regulatory purposes. Accordingly, handlers of the waste stream are subject to RCRA regulatory requirements.

   In its current rulemaking procedure to revise and expand the toxicity characteristic rule, EPA is establishing regulatory limits for additional organic constituents not included in the current rule. EPA is establishing these regulatory limits based primarily on the results of runs of the EPACML model.

5. U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States*, 109th edition (1989), Table 353.

6. National Science Foundation, *Academic/Science Graduate Enrollment and Support*, NSF Report 90-302, NSF, Washington, DC (Fall 1988), Table C-1.

7. Charles, K.G., *The Environmental Service Industry*, Hambrecht & Quist, Incorporated, Institution Research, New York (September 8, 1989).

8. Charles, pages 8, 12, 24, as adjusted by ICF.

9. U.S. Environmental Protection Agency, *National Air Pollutant Emission Estimates, 1940-1988*, EPA, Washington, DC (1989), Tables 3-45 and 3-46.

10. U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States*, 109th Edition (1989), Table 9-52.

11. Motor Vehicles Manufacturers Association, *Motor Vehicles Facts and Figures*, MVMA, Detroit (1989), page 88.

12. Federal Technology Transfer Act of 1986 (P.L. 99-502). Also see U.S. Senate Report No. 99-283 (1986).

13. Personal communication with D. Berg, U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, Washington, DC (January 1990). This provision of the Federal Technology Transfer Act is based, in large part, on experience under the Bayh-Dole Act. Under that Act, universities have been required since 1980 to share royalties for federally funded research with individual employee-inventors. Universities have found royalty sharing with their inventors to be a powerful incentive that increases the number of inventions reported, and encourages inventors to contribute to their commercialization of inventions. Part of the objective of the Federal Technology Transfer Act is to attempt to provide these same incentives in federal agencies.

14. Personal communication with C. Brunot, EPA Office of Research and Development, Washington, DC (February 1990).

15. U.S. Environmental Protection Agency, *Superfund Innovative Technology Evaluation (SITE) Program*, EPA/540/8-89/010, EPA, Washington, DC (November 1989), page 2.

16. Personal communication with D. Sanning, EPA Office of Research and Standards, Washington, DC (February 1990).

17. U.S. Environmental Protection Agency, *The Superfund Innovative Technology Evaluation Program: Technology Profiles, EPA/540/5-89/013, EPA, Washington, DC (November 1989), pages 97-98.*

18. EPA, *Technology Profiles*, pages 99-100; additional information obtained from personal communication with T. Wildeman, Colorado School of Mines (February 1990).

19. EPA, *Technology Profiles*, page 107. A very small amount of solvent typically will remain in the soil. This residual solvent is removed from the soil by "steam stripping," which is essentially the application of steam.

20. EPA, *Technology Profiles*, page 107.

21. EPA, *Superfund SITE Program*, page 2.

22. EPA, *Technology Profiles*, page 2.

23. U.S. Environmental Protection Agency, *SHIRCO Infrared Incineration System: Applications Analysis Report*. EPA/540/A5-89/010, Washington, DC (June 1989), pages 1-3.

24. Personal communications with J. Farlow and R. Hillger, EPA Office of Research and Development, Risk Reduction Laboratory, Washington, DC (January 1990). Other categories of methods for leak detection do not rely on internal ("in-tank") methods. Another category of methods is leak-effects monitoring, in which tank owners use monitoring wells or other approaches to detect leaks. The testing program described in the text did not deal with these other methods.

25. After constructing the testing facility, ORD performed baseline runs under a variety of scenarios commonly associated with leak-detection testing. This data represented a major new advance: the first comprehensive set of baseline data against which leak-detection equipment could be tested, verified, and validated. ORD then invited vendors of internal volumetric leak-testing services to participate. Different vendors used different configurations of hardware and different operating methods. As a first step, EPA modeled each vendor's hardware and methods, based on information provided by the vendor. The baseline data were run through the model for each vendor. Based on these results, EPA was able to estimate the accuracy and precision of vendor services (for example, based on a combination of their hardware and methods). As a next step, EPA invited the vendors to participate in field-testing, using special ORD testing apparatus to confirm the model results. Personal communications, Farlow and Hillger.

26. U.S. Environmental Protection Agency. *EPA International Strategy*, EPA, Washington, DC (January 1989). Additional information obtained from personal communications with E. Johnson, EPA Acting Director, Issues Division, Office of International Activities, Washington, DC (January 1990); with J. Lovelace, EPA Office of Research and Development, Washington, DC (January 1990); and with D. Strother, EPA Office of International Activities, Washington, DC (January 1990).

27. Personal communications with T. Gillette, Exxon Shipping Company; and with D. Johnson, EPA Alaska Field Office, Washington, DC (February 1990).

28. Personal communication with P. Preuss and R. Slotkin, EPA Office of Research and Development, Washington, DC (January 1990).

29. Personal communication with G. Waxmonsky, EPA, Washington, DC (January 1990).

30. This project was organized in connection with the 1972 U.S.-Soviet Environmental Protection Agreement Project (02.03-21), and was sponsored by the USDA/Forest Service and EPA; personal communication with R.D. Noble, Bowling Green State University (January 1990).

31. Also see Noble, R.D., J.L. Martin, and K.F. Jensen, eds., *Air Pollution Effects on Vegetation including Forest Ecosystems*, Proceedings of the Second U.S.-Soviet Symposium on Air Pollution Effects on Vegetation, September 13-25, 1988, USDA/Forest Service, Northeast Forest Experiment Station (September 1989).

32. See U.S. Environmental Protection Agency, "Summary Report of the First Meeting of the International Environmental Technology Transfer Advisory Board (IETTAB)," EPA, Washington, DC (December 7, 1989). Also see U.S. Environmental Protection Agency, "Advisory Committee Charter for the International Environmental Technology Transfer Advisory Board," EPA, Washington, DC (Filed with Congress October 31, 1989).

33. Personal communication with E. Berkey, President, Center for Hazardous Materials Research, University of Pittsburgh Trust (January 1990). Also see Center for Hazardous Materials Research, University of Pittsburgh Trust, *1988 Annual Report: Applied Research and International Technology Transfer*, University of Pittsburgh Applied Research Centers, Pittsburgh (1989), page 14.

34. "Vitrification of asbestos waste," *Hazardous Mater. Manage. Magazine* (November/December 1989); Personal communication with B. Moore, EPA Office of Research and Development, Washington, DC (January 1990).

35. "Pittsburgh: a growing place for environmental technology," *Pittsburgh High Technology* (First quarter 1989), 4(1):16; additional information obtained from personal communications with E. Berkey; and S. Laskowski, Deputy Regional Administrator, EPA Region III (January 1990).

January 24, 1989

In the dark early hours of January 24, 1989, three men moved out from the woods onto a snow-covered field in Vermont. Two were investigators from the Vermont Department of Environmental Conservation, and the third was a federal EPA Special Agent in the Office of Criminal Investigations. He was armed. They had the field under surveillance in an ongoing state/federal investigation of midnight dumping.

They were setting up surveillance equipment, when an 18-wheeler drove onto the field, its headlights off. As the agents approached, the truck turned and headed back for the road, where it was stopped by a state trooper.

The truck, overloaded with construction and demolition debris, was impounded, along with a bulldozer used in the operation. The driver, a local trucker who picked up the load near Boston, was arrested. He would be charged, along with the owner of the truck and the owner of the field, under a Vermont Solid Waste Dumping statute that carries a penalty of up to $25,000 and 6 months in jail.

CHAPTER 5

Environmental Enforcement

The evolution of environmental enforcement over the past two decades demonstrates both the gravity of environmental problems and the nation's determination to control them. In 1989 record numbers of environmental violations were reported in the United States, but many of the violators have already been brought back into compliance with regulations. The Environmental Protection Agency (EPA) alone took some 4,500 enforcement actions in 1989, and EPA-approved state programs reported another 12,800 actions. By year's end, violators were either back in compliance, on a compliance schedule, or facing a formal enforcement action.[1] Twenty years ago, such a caseload would have been unthinkable, and the few pollution cases then actively pursued by the government sometimes dragged on for years.

In 1989 the majority of environmental violations were corrected by administrative actions taken by federal, state, or local regulatory agencies. About 10 percent of EPA cases were referred for civil judicial action, most of which were settled by court-approved consent decrees. Out of 4,500 actions, only 60 violations

were referred for criminal prosecution. Other federal agencies that enforce environmental laws report similar ratios of criminal referrals to total enforcement actions.

Despite the small numbers, felony prosecutions of environmental crimes stand out as the major change in environmental enforcement over the past 20 years. A growing public reaction to those who knowingly damage the environment and endanger human life has been reflected in tougher enforcement provisions in environmental laws. Misdemeanors have been raised to felonies. Million-dollar fines are no longer uncommon, and corporate executives serve jail terms for knowing violations of the law.

Civil enforcement actions often are taken against large companies capable of absorbing even million-dollar penalties as just another cost of doing business. Civil judgments may carry little public stigma, but, in contrast, criminal sanctions can serve as effective deterrents. Incarceration is one cost of doing business that can't be passed on to the consumer.

The goal of environmental enforcement is not only to punish polluters and poachers, but, by means of timely and appropriate actions against significant violators, to deter others. The goal is not to close down the industries that built the American economy, but to motivate them, out of enlightened self interest, to clean their own houses.

Federal and state legislators have empowered environmental enforcers in both the public and private sectors—from the city policeman to the federal judge and from the individual citizen to large public-interest groups. Today environmental enforcers are armed with an array of tools—such as high-tech surveillance, environmental audits, contractor debarment, citizen suits—far more powerful than those available in 1970.

Historical Perspective

Historians describe 1970 as the Year of the Environment for the sheer volume of environmental initiatives begun, including the enforcement of environmental laws. Before 1970, few polluters were taken to court, because few pollution-control laws—state or federal—were written from an enforcement perspective. Early water and air legislation was meant to encourage compliance, and enforcement mechanisms were at best cumbersome and inefficient.

For example, in 1965 Delaware asked the federal government to take action to stop "a horrible" interstate "stench" caused by a rendering plant in Maryland.[2] The Secretary of Health, Education, and Welfare, then in charge of administering the Clean Air Act, called an enforcement conference, attended by representatives of the two states.

The conference recommended that Maryland require abatement of the odor. The HEW Secretary forwarded the recommendation to Maryland, and when no remedial action was taken, he scheduled a public hearing attended by representatives of the two states and the rendering plant. The Hearing Board made findings and recommendations to the Secretary, who then instructed the rendering plant to abate the odor. When it did not, the Secretary requested that the U.S. Attorney General file suit. Suit was filed, and in 1970, on dismissal of the plant's final appeal, the government ordered the first federal closing of a facility for air pollution.[3] The enforcement action, from first complaint to final closing, took five years.

At the time, few government attorneys wanted to handle pollution cases. Courts, especially at the state level, often were inclined to favor economic development over environmental protection.[4] Penalties for violations were minor, and, in the absence of definitive standards, evidence was problematic. Judges and juries had no technical measure for determining what constituted a pollution violation.

In August 1970 the newly established Council on Environmental Quality published the first report from the President to Congress on the state of the nation's environment.[5] In it, President Richard Nixon recommended national pollution standards and stronger enforcement authority with fines of $10,000 a day for air and water polluters, which were considered stiff penalties for the time.

Meanwhile, the states were struggling to set their own pollution standards. The federal government was willing to help, but its pollution programs were fragmented in five executive agencies. Nixon's proposal to consolidate pollution-control efforts in a new federal agency was then before Congress.

In October 1970 the U.S. Department of Justice established a Pollution Control Section in its Division of Land and Natural Resources. This Division, previously occupied with land acquisition and boundary disputes, found itself at the forefront of a national anti-pollution campaign. The public wanted action, but Justice Department attorneys were frustrated by the lack of enforcement provisions in federal pollution-control laws. Thus they turned to the venerable Rivers and Harbors Act, passed back in 1899 to regulate mining operations. A section of the law called the Refuse Act forbade the discharge of refuse matter into navigable waters. The original authors of the law were thinking more of physical obstructions to navigation than pollution, but they wrote a law that has adapted with the times.

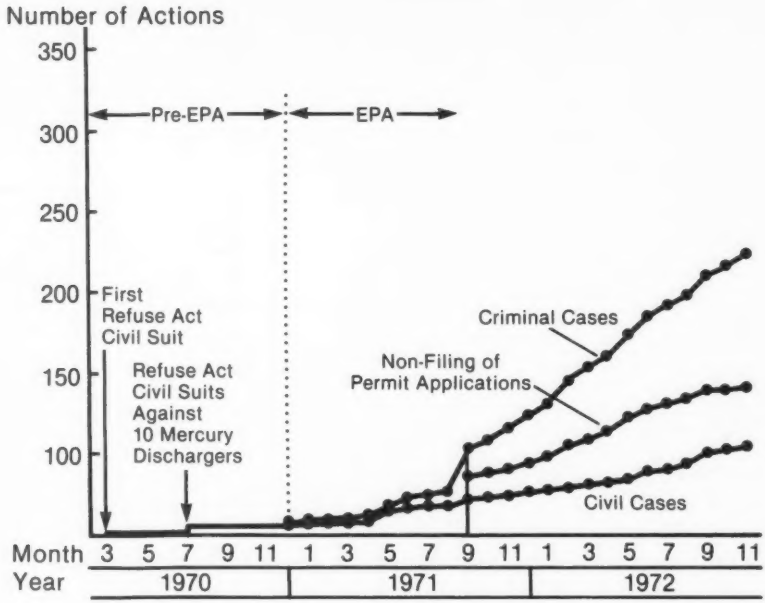
When the Supreme Court ruled in the late 1960s that the Refuse Act could apply to discharges of gasoline and oil, federal attorneys finally were armed with an anti-pollution law with teeth. Violators could be found guilty of a misdemeanor, punishable by a $2,500 fine and/or one year in jail. In 1970 the Justice Department filed 129 criminal pollution cases, far more than in any previous year (Table 5-1 and Figure 5-1).

Table 5-1.—Litigation Initiated by the Department of Justice under the Refuse Act, 1961–73.

FISCAL YEAR	CRIMINAL				CIVIL		
	ACTIONS INITIATED	CONVICTIONS	FINES PAID	BOUNTIES AWARDED	ACTIONS FILED	COMPLAINT DISMISSED	ACTIONS TERMINATED BY ENTRY OF DECREE
			..... $				
1961	15	(*)	(*)	(*)	0	0	0
1962	16	(*)	(*)	(*)	0	0	0
1963	20	(*)	(*)	(*)	0	0	0
1964	45	(*)	(*)	(*)	0	0	0
1965	32	(*)	(*)	(*)	0	0	0
1966	42	(*)	(*)	(*)	0	0	0
1967	56	(*)	(*)	(*)	0	0	0
1968	41	(*)	(*)	(*)	0	0	0
1969	46	42	(*)	(*)	0	0	0
1970	129	59	(*)	(*)	2	0	0
1971	191	127	174,800.00	18,900.00	58	0	24
1972	198	200	216,500.00	36,500.00	68	9	29
1973	106	132	336,450.00	20,750.00	36	4	19

*No figures available.
Source: *1973 Annual Report of the Attorney General of the United States*, U.S. Department of Justice, Washington, DC (1974), page 122.

Figure 5.1—EPA Enforcement Actions under the Refuse Act, 1970-72.



Source: Ruckelshaus, W.D., *The First Two Years: A Review of EPA's Enforcement Program*, EPA, Washington, DC (1973), page 15.

In the first civil pollution case under the Refuse Act, the federal government enjoined the dumping of hot water into Biscayne Bay by a power company. Action was taken against 10 major dischargers of mercury and against several steel companies to enjoin their discharges of cyanides and phenols, and in one of the year's major pollution incidents, Chevron Oil Company was penalized $1 million for an extensive oil spill in the Gulf of Mexico.[6]

In addition to activism on the part of public enforcers, 1970 witnessed the birth of the federal citizen suit. The Clean Air Act amendments of that year gave private citizens the authority to sue polluters directly or to sue regulatory agencies for failure to perform nondiscretionary duties.

President Nixon began the Year of the Environment by appointing the first Council on Environmental Quality to advise him on environmental matters. He brought the year to a close by establishing the National Oceanic and Atmospheric Administration and the Environmental Protection Agency. The enforcement implications of the actions were apparent, and national magazines of the day described Nixon's new "environmental troika—CEQ, EPA, and NOAA" as "policemen for pollution."[7]

Public Enforcement Today

Unlike the fragmented approach typical 20 years ago, environmental enforcers today are beginning to pool their expertise in teams of local, state, and federal personnel. The government scientists, engineers, investigators, and attorneys who share responsibility for enforcing environmental laws are finding that they can share caseloads as well. Jurisdiction is often decided as a case develops. Under certain statutes, the federal government is granted primacy and may choose to file a precedent-setting case, but the majority of environmental statutes delegate enforcement to the states.

Many environmental statutes are structured to be self-enforcing, at least by permitted facilities. For example, hazardous waste laws require permitted facilities to submit periodic reports on the pollutants they generate. If a report is late or if it indicates that an environmental standard is not being met, a regulatory agency can initiate an enforcement action to bring the facility back into compliance.[8] Well-intentioned facilities monitor and report on their own operations, but today enforcers also must track highly profitable businesses that dispose of wastes illegally.

Federal Government

In 1989 a dozen different federal agencies were actively enforcing environmental laws. Government personnel from diverse disciplines cooperated to enforce laws that control pollution and conserve natural resources (Table 5-2). Agencies such as the Fish and Wildlife Service, the National Marine Fisheries Service, the Forest Service, and the Park Service enforced laws that conserve the nation's flora, fauna, and natural habitat, and EPA cooperated closely with the Army Corps of Engineers, the Coast Guard, and the FBI, among others, to enforce pollution control.

Table 5-2.—Enforcement Provisions of Environmental Laws Passed, Amended, and/or Reauthorized by Congress, 1970–89.

LAW	DATE SIGNED	ENFORCEMENT PROVISIONS
National Environmental Policy Act (NEPA)	1/1/70	The Council on Environmental Quality (CEQ) in the Executive Office of the President administers action-forcing provisions that require federal agencies to submit environmental assessments and impact statements on proposed actions. Judicial review has evolved as the chief enforcement tool.
Clean Air Act (CAA) Amendments	1970 1977	The Environmental Protection Agency (EPA) sets national air standards and delegates enforcement to the states through EPA-approved programs. Penalties up to $25,000/day and/or 1 year in jail; double for second convictions; citizen suit provision.
Occupational Safety and Health Act (OSH Act)	1970	The Occupational Safety and Health Administration (OSHA) in the Department of Labor sets and enforces environmental standards in the workplace. Civil penalties $1,000–10,000/day; criminal fines up to $20,000 and/or 1 year in jail.
Federal Water Pollution Control Act amendments Clean Water Act (CWA) Amendments Amendments Amendments	1972 1977 1981 1987 1988	EPA sets national water standards and delegates enforcement to the states through EPA-approved programs. EPA and the DOD/Army Corps of Engineers enforce wetlands regulations, and the DOT/Coast Guard enforces oil-spill provisions. Penalties up to $25,000 after informal administrative hearing; up to $125,000 after formal EPA adjudicatory hearing; civil penalties $10,000–25,000/day; criminal sanctions for misdemeanors and felonies; felony fines up to $250,000 and/or 15 years in jail for individual; $1 million fine for an organization; citizen suit provision.

Table 5-2.—Enforcement Provisions of Environmental Laws Passed, Amended, and/or Reauthorized by Congress, 1970–89 (cont.).

LAW	DATE SIGNED	ENFORCEMENT PROVISIONS
Federal Insecticide, Fungicide, Rodenticide Act (FIFRA)	1972	EPA registers and classifies pesticides, certifies applicator training, and delegates enforcement to the states through EPA-approved programs. Administrative penalties $500–5,000; criminal fines $1,000–50,000 and/or 30 days–1 year in jail.
Marine Protection, Research, and Sanctuaries Act (MPRSA) Amended by Ocean Dumping Ban Act	1972 1988	EPA, DOD/Army Corps of Engineers, and DOT/Coast Guard assist DOC/NOAA National Marine Fisheries Service enforce provisions regulating ocean dumping. Department of State handles international violations. Amendments ban ocean dumping of sludge and infectious medical waste. Civil penalties up to $50,000/violation; criminal sanctions; citizen suit provision.
Marine Mammal Protection Act (MMPA) Amendments	1972 1981	DOI/Fish and Wildlife Service and DOC/NOAA National Marine Fisheries Service enforce a ban on the taking of any marine mammal on the high seas. NOAA enforces the ban for whales, porpoises, seals, and sea lions. FWS protects walrus, polar bears, manatees, and sea otters. Amendments limit the incidental taking of porpoises by commercial fishermen. State Department handles international violations. Civil penalties up to $10,000/violation; criminal fines $20,000/violation and/or 1 year in jail.
Noise Control Act (NCA) Amended by Quiet Communities Act	1972 1978	EPA sets standards and delegates enforcement to the states through EPA-approved programs. OSHA enforces the law in the workplace. Civil fines up to $10,000/day; criminal fines up to $25,000 and/or 1 year in jail; double for second convictions.
Endangered Species Act (ESA) Amendments Reauthorized	1973 1982 1988	DOI/Fish and Wildlife Service, DOC/NOAA National Marine Fisheries Service, DOT/Coast Guard, Department of Agriculture, and Department of the Treasury enforce the law. Civil penalties $500–25,000/violation; criminal fines $25,000–50,000 and/or 6 months–1 year in jail.
Safe Drinking Water Act (SDWA) Amendments Lead Contamination Control Act Amendments	1974 1977 1986 1988	EPA sets national standards and delegates enforcement to the states through EPA-approved programs. Civil penalties up to $10,000/day; criminal sanctions; citizen suit provision.
Atomic Energy Act Amendments Amended by the Uranium Mill Tailings Radiation Control Act	1974 1978	The Nuclear Regulatory Commission enforces the Atomic Energy Act and its amendments; civil penalities; criminal sanctions. EPA sets radiation emission standards.

Table 5-2.—Enforcement Provisions of Environmental Laws Passed, Amended, and/or Reauthorized by Congress, 1970–89 (cont.).

LAW	DATE SIGNED	ENFORCEMENT PROVISIONS
Toxic Substance Control Act (TSCA) Amended by Asbestos Hazard Emergency Response Act (AHERA)	1976 1986	EPA tests new chemicals and bans those that pose unreasonable risk to public health or the environment. Civil penalties up to $5,000/day; criminal sanctions; citizen suit provision. Amendments authorize EPA to set asbestos standards and certify training of inspectors and workers. Civil penalties up to $5,000 a day.
Resource Conservation and Recovery Act (RCRA) Amended by the Hazardous and Solid Waste Act (HSWA) Amendments Amended by Medical Waste Tracking Act	1976 1984 1986 1988	EPA enforces cradle-to-grave tracking of hazardous wastes and delegates enforcement to states through EPA-approved programs. Felony fine up to $250,000 or 15 years in jail for an individual or $1 million for an organization; citizen suit provision.
Hazardous Material Transportation Act (HMTA)	1976	Department of Transportation and Department of the Treasury Customs Service enforce the packaging and transport of hazardous material on land and sea and in the sky. Civil penalties up to $50,000; criminal fines $25,000 and/or 5 years in jail.
Magnuson Fishery Conservation and Management Act (MFCMA) Amendments	1976 1988	DOC/NOAA National Marine Fisheries Service enforces fisheries regulations in a U.S. Exclusive Economic Zone within 200 nautical miles of the United States. Civil fines up to $25,000/violation and forfeiture of a fishing vessel; criminal fines up to $50,000 and/or 6 months in jail.
Surface Mining Control and Reclamation Act (SMCRA)	1977	DOI/Office of Surface Mining Reclamation and Enforcement enforces regulations for cleanup of surface mining sites. Criminal fines of up to $5,000 and/or 1 year in jail.
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) Superfund Amendments and Reauthorization Act (SARA) Emergency Planning and Community Right-to-Know Act (EPCRA)	1980 1986 1986	EPA enforces regulations requiring responsible parties to clean up hazardous substance sites or to cover the costs of government cleanups funded by the multi-billion dollar Superfund set up by Congress for emergency use. DOD/Army Corps of Engineers and some states cooperate with EPA on removal and remedial actions. EPA enforces Title III of SARA that requires all manufacturers, importers, processors, and users of more than 300 hazardous chemicals to report annually on releases to the environment; felony sanctions.

Table 5-2.—Enforcement Provisions of Environmental Laws Passed, Amended, and/or Reauthorized by Congress, 1970–89 (cont.).

LAW	DATE SIGNED	ENFORCEMENT PROVISIONS
Lacey Act Amendments	1981	DOI/Fish and Wildlife Service and DOC/NOAA National Marine Fisheries Service enforce a ban on importation, possession, or interstate transport of wild plant and animal species taken in violation of state, federal, Indian, or foreign law. Civil penalties $10,000; criminal fines $20,000 and/or 5 years in jail. Fish, wildlife, or plants involved in violations are subject to forfeiture as are any vessels, vehicles, or aircraft.
Nuclear Waste Policy Act (NWPA)	1982	Nuclear Regulatory Commission enforces regulations regarding the storage and disposal of high-level radioactive waste, spent nuclear fuel, and low-level nuclear waste. EPA sets standards for radiation in surface and drinking water, air, precipitation, and milk.
Federal Food and Drug Control Act (FFDCA)		EPA sets maximum legal limits for pesticide residues on food and feed grains. The Department of Agriculture enforces tolerances for meat and poultry, and the Food and Drug Administration enforces tolerances for all other food products in interstate commerce.
Shore Protection Act (SPA)	1988	DOT/Coast Guard enforces regulations regarding pollution of beaches and coastlines. Civil penalties $10,000–25,000/day; criminal fines and/or 3 years in jail; vessels involved with violation liable for fines.

Source: *Federal Environmental Laws*, West Publishing Company, St. Paul, Minnesota (1989).

Environmental Protection Agency

Within EPA, the Office of Enforcement and Compliance Monitoring enforces pollution laws governing air, water, hazardous wastes, and toxics/pesticides. Through 10 EPA regional offices, enforcement personnel cooperate with U.S. attorneys, state attorneys general, district attorneys, as well as with other federal and state agencies to enforce nine major statutes and a number of minor ones.[9] A criminal unit, established in 1982, consisted of eight attorneys in the Washington office, at least one attorney in each of the 10 regional offices, and 49 investigators, most with criminal justice experience.

Criminal charges are sought for significant violations. In contrast to civil cases, most criminal leads come from sources outside EPA, primarily from disgruntled employees of violators. After a case is referred to the Department of Justice, EPA criminal attorneys occasionally may be asked to serve on the trial team. In Boston, Atlanta, and Dallas, EPA personnel have been designated special assistant U.S. attorneys to try criminal cases. In seven years of operation, the EPA Office of Criminal Enforcement has referred 300 cases to the Department of Justice.

In practice, EPA has written regulations and established enforcement precedents—administrative, civil, and criminal—for new federal statutes, before turning enforcement programs over to the states. This has been the case with Clean Air and Clean Water permit programs, and regulations for hazardous substance programs are in review.

Clean Air Act

EPA sets national Clean Air standards and delegates enforcement to the states through agency-approved programs. The majority of Clean Air violations are corrected by administrative actions (see Table 5-3 for a compilation of EPA administrative enforcement actions). At the beginning of 1989, EPA and the states identified 696 facilities in significant violation of Clean Air Act regulations. At year's end, over 230 of these facilities had been brought into compliance 97 were following an enforceable compliance schedule, and 243 were subject to a formal enforcement action.

In 1989 EPA referred 92 Clean Air violations to the Department of Justice for civil action, a decrease from the record of 149 cases referred in 1979 (Table 5-4). EPA-approved state programs referred 96 Clean Air Act cases for state judicial action in 1989 and took 1,139 administrative actions (Table 5-5).

In 1989 enforcement actions were taken against a variety of violators, ranging from Fortune 400 corporations to neighborhood garages. For example, in Wisconsin a major pulp and paper company that was releasing large quantities of sulfur dioxide entered into a federal consent decree and agreed to install $9 million worth of pollution-prevention equipment and pay a

Table 5-3.—EPA Administrative Enforcement Actions Initiated by Act, Fiscal Years 1972–89.

FISCAL YEAR	CAA	CWA/SDWA	RCRA	CERCLA	FIFRA	TSCA	TOTAL
FY72	0	0	—	—	860	—	860
FY73	0	0	—	—	1,274	—	1,274
FY74	0	0	—	—	1,387	—	1,387
FY75	0	738	—	—	1,614	—	2,352
FY76	210	915	0	—	2,488	0	3,613
FY77	297	1,128	0	—	1,219	0	2,644
FY78	129	730	0	—	762	1	1,622
FY79	404	506	0	—	253	22	1,185
FY80	86	569	0	0	176	70	901
FY81	112	562	159	0	154	120	1,107
FY82	21	329	237	0	176	101	864
FY83	41	781	436	0	296	294	1,848
FY84	141	1,644	554	137	272	376	3,124
FY85	122	1,031	327	160	236	733	2,609
FY86	143	990	235	139	338	781	2,626
FY87	191	1,214	243	135	360	1,051	3,194
FY88	224	1,345	309	224	376	607	3,085
FY89	336	2,146	453	220	443	538	4,136

Source: U.S. Environmental Protection Agency, *FY 1989 Enforcement Accomplishments Report*, EPA, Washington, DC (1990).

Table 5-4.—EPA Referrals to the Department of Justice, Fiscal Years 1972–89.*

FISCAL YEAR	CIVIL				CRIMINAL						
							DEFENDANTS		SENTENCING		
	AIR	WATER	HAZ. WASTE	TOXICS	REFERRALS	PROSECUTIONS	CHARGED	CONVICTED	TERM	JAIL	PROBATION
									..... *months*		
FY72	0	1	0	0							
FY73	4	0	0	0							
FY74	3	0	0	0							
FY75	5	20	0	0							
FY76	15	67	0	0							
FY77	50	93	0	0							
FY78	123	137	2	0							
FY79	149	81	9	3							
FY80	100	56	53	1							
FY81	66	37	14	1							
FY82	36	45	29	2	20	7	14	11	0	0	0
FY83	69	56	33	7	26	12	34	28	0	0	534
FY84	82	95	60	14	31	14	36	26	6	6	552
FY85	116	93	48	19	40	15	40	40	78	44	882
FY86	115	119	84	24	41	26	98	66	279	203	828
FY87	122	92	77	13	41	27	66	58	456	100	1,410
FY88	86	123	143	20	59	24	97	50	278	185	1,284
FY89	92	94	169	9	60	43	95	72	325	208	1,045

*Excluding water enforcement actions, civil and criminal, under the Refuse Act. See Figure 5-1.
Source: U.S. Environmental Protection Agency, *FY 1989 Enforcement Accomplishments Report*, EPA, Washington, DC (1990).

Table 5-5.—State Environmental Agency Enforcement Actions by Program, Fiscal Years 1985–89.

	FIFRA	WATER	AIR	RCRA	TOTAL
Administrative Orders					
FY85	8,899	2,936	448	459	12,742
FY86	6,055	2,827	760	519	10,161
FY87	5,922	1,663	907	613	9,105
FY88	5,078	2,887	655	743	9,363
FY89	6,698*	3,100	1,139	1,189	12,126
Judicial Referrals					
FY85	8,899	137	182	82	401
FY86	6,055	221	162	25	408
FY87	5,922	286	351	86	723
FY88	5,078	687	171	46	904
FY89	6,698*	489	96	129	714

*Includes 3,409 warning letters.
Source: U.S. Environmental Protection Agency, *FY 1989 Enforcement Accomplishments Report*, EPA, Washington, DC (1990).

$200,000 penalty. In Texas, the owners of a muffler shop that had removed catalytic converters from over 20 vehicles were penalized $1,750 per vehicle in the highest civil penalty assessed by a federal court for violation of the anti-tampering prohibition of the Clean Air Act.

Clean Water Act and Safe Drinking Water Act

In its early years, EPA referred water pollution abatement cases to the Department of Justice for action under the Refuse. In 1972 federal prosecutors obtained 200 criminal convictions for the discharge of pollutants into navigable waters. That same year, amendments to the Federal Water Pollution Control Act superceded the Refuse Act as the primary basis for bringing judicial actions against industries, and new regulations were written.[10] As was the case with the Clean Air Act, the Clean Water Act

authorized EPA to set national standards and assist the states in enforcing them.

After a 3-year phase-in period, EPA began referring Clean Water violations to the Department of Justice for civil actions. The numbers have fluctuated over the years from a high of 137 referrals in 1978 to 94 referrals in 1989. As administrative sanctions increased, only the most serious violations or the most recalcitrant violators were referred to the Department of Justice; most violations were resolved administratively. In 1975 Clean Water Act and Safe Drinking Water Act administrative actions together totaled 738; by 1989 that number had tripled.

For the Clean Water Act alone in 1989, EPA and the states listed 514 facilities in significant noncompliance with regulations. Of these, 236 were returned to compliance and 181 were subject to enforcement actions, including a growing number of criminal prosecutions.

In Massachusetts, for example, a 1989 federal enforcement action led to that state's first environmental prosecution resulting in a jail term. Two owners of an electroplating shop in Lowell were incarcerated for discharging, over a period of years, wastewater contaminated with high levels of lead, copper, and nickel. They were discharging the pollutants into the Lowell sewer system and directly into a tributary of the Merrimack River, which is the source of drinking water for Lowell and other communities.

Criminal sanctions have been strengthened for knowing violations of dredge-and-fill regulations, and in 1989 two Florida men received federal jail terms for the unpermitted excavation and discharge of dredge spoils on a wetlands site. A condition of their sentencing was that, on release from prison, they restore the site. In Pennsylvania, the first federal wetlands case to go before a jury resulted in a fine of $202,000 and three years in jail for the owner of a 14-acre wetlands property, who filled the site despite cease-and-desist orders from the U.S. Army Corps of Engineers and a temporary restraining order from a federal court.[11]

The Clean Water Act laid the groundwork for EPA to bring all publicly owned sewage-treatment centers into compliance with national standards. Over the years, deadlines have been extended, yet a number of cities remain in noncompliance. In 1989 EPA took enforcement actions against 61 municipalities. Of

these, 19 were civil court actions against publicly owned wastewater treatment facilities that were not implementing approved pretreatment programs. The highest Clean Water Act penalty obtained against a municipality was imposed in 1989 when a Denver sewage district was assessed $1.1 million.

Under the Safe Drinking Water Act, EPA tracks significant noncompliance by public water supply systems. In the 1980s groundwater began receiving enforcement attention, and EPA-approved state programs now enforce maximum contaminant levels and regulate injection of wastes into deep wells.

In a 1989 civil action, a petroleum company in Indiana, as part of a federal consent decree, agreed to come into compliance with regulations for underground injection control at nine of its injection wells and to pay a $55,000 fine. In another case, EPA issued an administrative order against the owners of a Superfund site, because contaminants had migrated off site, contaminating drinking wells. The polluters were required to provide alternate water supplies to affected residents.

Federal Insecticide, Fungicide, and Rodenticide Act

The FIFRA amendments of 1972 authorized EPA to register new pesticides, test all pesticides on the market, and certify applicators of restricted-use pestici. In 1989 cooperative state/federal actions were taken against 142 facilities in significant noncompliance with FIFRA regulations. By year's end, all but 26 cases had been resolved.

Over the years, FIFRA enforcement has changed focus from assuring that insecticides, fungicides, and rodenticides actually kill pests to assuring that they do not at the same time harm human health or the environment. This midstream change has placed EPA in what some call "the FIFRA trap."[12] To suspend or cancel a pesticide, EPA must employ a "tortuous mechanism" fraught with "procedural obstacles" that may account for the current decline in FIFRA enforcement actions. In 1972 EPA took 860 administrative actions against FIFRA violators. The figures rose to a high of 2,488 actions in 1976, and then fluctuated to the 1989 figure of 443 actions. In 1985 the states initiated 8,899 FIFRA administrative orders; in 1989 that number had declined

to 6,698. The figures suggest that it may have been simpler to enforce regulations requiring pesticides to kill pests than it is to ensure that the same pesticides do not pollute the environment.

Under the Federal Food, Drug, and Cosmetic Act (FFDCA), EPA sets maximum legal limits or tolerances for pesticides on food or feed crops. The Department of Agriculture enforces pesticide tolerances for meat and poultry, and the Food and Drug Administration in the Department of Health and Human Services enforces tolerances for all other food products in interstate commerce.

Marine Protection, Research, and Sanctuaries Act

Also known as the Ocean Dumping Act, the Marine Protection, Research, and Sanctuaries Act (MPRISA) authorizes EPA and the Corps of Engineers to regulate ocean dumping by means of a permit system. A 1988 amendment, known as the Ocean Dumping Ban Act, prohibits dumping of sewage sludge, industrial waste, and infectious medical wastes into the ocean, and establishes a scheme for phasing out currently permitted dumping of sludge.

To enforce the law, the Coast Guard monitors barges, using on-board inspections and electronic surveillance. Barges are fitted with "black boxes" that measure the vessels' draft in the water and transmit the data to a Coast Guard vessel. A sudden change in a barge's draft prior to reaching a designated site could indicate illegal ocean dumping. Although only a few permits have been issued, permittees are tracked carefully because of the potential for pollution and the public's reaction to ocean dumping in recent years.

Toxic Substance Control Act

Passed in 1976, the Toxic Substance Contol Act (TSCA) authorizes EPA to test new chemicals and to maintain an inventory of chemicals in commercial use. The law bans the manufacture of compounds that pose an unreasonable risk to human health or the environment, such as polychlorinated biphenyls (PCBs).

At the beginning of 1989 EPA reported 452 significant noncompliance cases involving asbestos and PCBs, including asbestos in schools. By the end of the year, 336 of the cases had been resolved, but meanwhile, 468 new cases had been identified, and 397 enforcement actions were taken.

Most TSCA violations are corrected administratively. In 1979, when EPA began taking administrative actions against TSCA violators, 22 actions were recorded. After increasing to a high of 1,051 in 1987, actions decreased to 538 in 1989. TSCA referrals to the Department of Justice have never been extensive. Beginning with 3 civil referrals in 1979, the numbers increased to a high of 24 cases in 1986 and stood at 9 referrals in 1989.

Resource Conservation and Recovery Act

The 1976 EPA annual report on enforcement listed "Air, Noise, Pesticides, and Water" in its title, but not hazardous waste.[13] In October of that year, Congress amended the Solid Waste Disposal Act to regulate hazardous wastes from generation to disposal—cradle to grave. Those amendments, known as the Resource Conservation and Recovery Act (RCRA), authorized EPA to work with the states to enforce hazardous waste regulations.

EPA administrative enforcement under RCRA has fluctuated from 189 actions in 1981 to 453 actions in 1989. RCRA civil referrals to the Department of Justice increased in 1989 to a record high of 169 cases; RCRA criminal referrals also increased. State RCRA enforcement showed an increase in administrative actions and a decrease in judicial referrals by nearly half.

During 1989 EPA and the states identified 664 facilities in significant violation of RCRA regulations. By the end of the year, 78 facilities had been returned to compliance. Of the 88 percent still out of compliance, 300 were on compliance schedules, and 284 had enforcement actions pending against them. Included in the statistics are actions taken to regulate underground gas and oil storage tanks.

RCRA penalties, like those of many environmental laws, are increasing. For example, a Louisiana company recently pled guilty to one felony RCRA charge for the unpermitted storage of hazardous waste and to two misdemeanor charges under the Refuse Act. The owners agreed to pay a million-dollar fine.

As states initiate EPA-approved RCRA programs, joint state/federal enforcement actions are becoming more common. For example, in 1989 a cooperative action by EPA special agents and Connecticut Department of Environmental Protection investigators led to a guilty plea by a chemical corporation to one felony count relating to hazardous waste disposal practices and to two felony counts for making false statements to EPA. The investigation revealed hundreds of buried drums containing hazardous waste and a trench into which 2,000 gallons of sulfuric acid had been dumped. The company also paid a million-dollar fine, half of which was directed back to the state for site cleanup. A former vice-president of the company pled guilty to the same charges and received a 3-year suspended sentence and a $10,000 fine.

Uranium Mill Tailings Radiation Control Act

In 1978 the Uranium Mill Tailings Radiation Control Act authorized EPA to set generally applicable standards limiting radiation releases from mill tailings at active and inactive uranium mills and underground uranium mines. The Nuclear Regulatory Commission enforces the law.

Comprehensive Environmental Response, Compensation, and Liability Act

The law authorizing Superfund was passed in 1980 and amended in 1986 by the Superfund Amendments and Reauthorization Act. CERCLA and SARA require the parties responsible for sites contaminated by hazardous materials to conduct cleanups under government supervision. In 1989 an EPA inventory identified 27,000 such sites nationwide, and a National

Priorities List ranked the 1,077 most dangerous sites. If responsible parties are unwilling to clean up sites, EPA may issue an administrative order. The agency began taking administrative actions against violators in 1984, when it issued 137 orders. The numbers fluctuated to a high of 224 actions in 1988 and declined slightly to 212 Superfund administrative actions in 1989. If a cleanup order is ignored, EPA can proceed to clean up the site with Superfund monies, but responsible parties then may be liable for punitive damages up to triple the cost of federal remedial work.

In 1989 EPA referred 153 Superfund cases to the Department of Justice for civil action. Remedial-action consent decrees valued at $594 million were completed for 48 of these sites. Reimbursements for past work by EPA brought this total to over $800 million. For the first time since the program began, private parties undertook more remedial actions in 1989 than were begun by the government under Superfund.

Because of the cost of site cleanups, multi-million-dollar settlements are common in Superfund cases. In Massachusetts, for example, two consent decrees provided for a $33.1 million settlement with 48 responsible parties, who will work at three sites, while EPA continues at a fourth. The companies had dumped hazardous wastes in septic systems and in open fields next to a residential neighborhood, causing soil and groundwater contamination. Residential drinking water supplies had to be replaced.

The Emergency Planning and Community Right-to-Know Act (EPCRA), Title III of SARA, requires specified facilities to report releases of any of 300 toxic chemicals. EPA maintains a computer database, called the Toxic Chemical Release Inventory (TRI), which aggregates the information. In 1987 EPA received 75,000 reports of releases from 18,000 facilities. The database, available simultaneously to EPA and the public through computer telecommunications, is proving valuable to both public agencies and private citizens who seek to enforce environmental laws.[14]

Nuclear Regulatory Commission

The Nuclear Regulatory Commission (NRC), created by the Energy Reorganization Act of 1974, enforces U.S. laws governing civilian uses of nuclear material. Such uses include the operation of nuclear power plants and applications in medicine, industry, and research. To protect public health and safety, the environment, and national security, NRC enforces the Atomic Energy Act, the Uranium Mill Tailings Radiation Control Act, the Nuclear Waste Policy Act, and other statutes dealing with radiation.

The NRC Office of Enforcement manages the agency's enforcement program. NRC inspections are conducted by approximately 550 full-time equivalents located in the five NRC regions and at headquarters. The inspectors submit compliance reports, as do licensees themselves. Enforcement actions include written notices of violations, civil penalties, and orders. In 1988 the largest civil penalty to date, $1.25 million, was issued to a Pennsylvania nuclear power plant for failure to detect, report, and deal with inattentive operators, 33 of whom were penalized $500-$1,000 each. In 1989 a Colorado mining company received a civil penalty of $3,750 for violating the Uranium Mill Tailings Radiation Control Act by failing to monitor radon emissions from a uranium mine.

The NRC Office of Investigations, with a staff of 35 investigators, handles allegations of willful violations. In 1988 NRC investigators opened 91 new cases and closed 107 cases, 28 of which were referred to the Criminal Division of the Department of Justice for prosecution. A major investigation focused on allegations that counterfeit and defective parts were being sold to nuclear power plants, the National Aeronautics and Space Administration (NASA), the Department of Defense (DOD), and other federal agencies. Ten criminal search-and-seizure warrants were executed in southern California, and two employees of a nuclear materials firm pled guilty to charges of conspiracy to defraud the government. They were sentenced to three years probation and fined $10,000 and $2,500. The company was fined $100,000, and a former president of the firm was convicted and sentenced to two years in jail, three years probation, and a $100,000 fine. Also in 1988 an investigation of an americium-241

spill at Wright-Patterson Air Force Base in Dayton, Ohio, led to a guilty plea by a former radiation safety officer, who admitted illegal possession of radioactive material.[15] As a result of the investigation, NRC collected a civil penalty of $102,500 from the Air Force.

However, the majority of NRC violations between 1974 and 1989 were cases of negligence that could be resolved administratively. In 1989 over 1,000 notices of violations were written, 100 civil penalties were imposed, and 14 orders were issued. During the past two decades, civil penalties have increased sharply. In 1974 the total for the year was somewhat over $100,000; by 1981 it had risen to over $1 million, and 1988 saw the first million-dollar penalty. Total civil penalties issued in 1989 exceeded $5.6 million.

Department of Defense

The 1972 Clean Water Act amendments authorized the U.S. Army Corps of Engineers (COE) to issue permits for the deposit of dredge-and-fill material in the nation's navigable waters. At first, permits were only required for waters used in commercial navigation, but a 1975 citizen's suit led to a court ruling that included all waters of the United States, including the territorial seas, and all coastal and inland wetlands. Then in 1977 amendments to the Clean Water Act gave EPA-approved states the authority to establish permit programs to protect waters and wetlands other than those traditionally used for navigation. Today EPA and COE cooperate on wetlands enforcement.

The COE Clean Water Act caseload increased from 1,000 complaints in 1977 to over 7,000 in 1989, about half of which turned out to be actual violations of the law. In the same time, enforcement staff increased from 600 to 800 nationwide. Most violations are handled within the agency, but in 1989 the Corps referred 125 cases to EPA for administrative penalties and 45 cases to the Department of Justice for judicial actions. The Corps issues permits for discharges into navigable waters under the Rivers and Harbors Act and permits for dredge-and-fill operations under the Ocean Dumping Act. In 1989 ocean-dumping permits were issued for 27 coastline-construction and harbor-maintenance projects, and 12 ocean-dumping violations were detected.[16]

Department of the Interior

One of the primary duties of the Department of the Interior's Fish and Wildlife Service (FWS) is to enforce the Lacey Act. This legislation, passed in 1900 to prohibit interstate commerce in unlawfully taken wildlife, was inspired by the shooting of the last buffalo living in Yellowstone National Park. In 1981 Congress amended the Lacey Act to strengthen enforcement provisions and establish felony offenses punishable by a penalty of $20,000 and/or five years in jail. The FWS also enforces the Endangered Species Act, the Migratory Bird Treaty Act, the Marine Mammal Protection Act, the Airborne Hunting Act, and the Bald and Golden Eagle Protection Act, among others.

In recent years, the wildlife black market has become highly profitable. An eagle-feather headdress may bring $10,000, and a live American hunting falcon sells for $100,000 in some Middle-East countries. High profits attract wildlife smugglers who operate through crime rings that also smuggle guns and drugs. Thus the Division's 207 special agents have full arrest and firearm powers.

In addition, 56 uniformed inspectors staff major ports of entry to monitor import and export shipments of living wildlife and wildlife products. In 1988 they inspected 18,289 shipments, about one-fifth of the total wildlife shipments received that year at U.S. ports of entry. The value of the shipments inspected was close to $1 billion.[17]

Between 1986 and 1988 violations detected through port inspections, undercover operations (Table 5-6), complaints, and investigations led to some 27,000 enforcement actions. Returns to the government from civil and criminal penalties and property forfeitures for the three years totaled $8.8 million, and sentencing included 457 years of jail terms. The majority of actions were handled by FWS enforcement personnel or by Department of Interior attorneys. Cases requiring judicial actions were referred to the Wildlife and Marine Resources Section of the Department of Justice or to the office of a U.S. attorney.

Table 5-6.—Criminal Cases Investigated Covertly by the Branch of Special Operations in the Division of Law Enforcement, DOI/Fish and Wildlife Service, 1981–89.*

TAKEDOWN YEAR	CASE	ARRESTS	FINES	SENTENCING				
				JAIL		PROBATION		COMMUNITY SERVICE
				years	*months*	*years*	*months*	*hours*
1981	GA Live Reptiles	27	227,475	9	7	93	0	0
	SD Deer	22	30,100	21	7	38	0	300
1982	CA Klamath Salmon	26	1,500	3	10	11	0	0
	AL Deermeat	24	18,784	38	1	32	0	0
1983	SD Bald Eagles	9	45,605	10	9	49	0	725
1984	MT Operation Falcon	36	501,071	3	0	78	6	1,615
	WY Operation Trophykill	33	128,138	51	6	95	4	2,977
1985	PA Striped Bass	44	385,722	18	0	93	3	2,494
1987	NM/AZ Eagles	17	42,620	15	0	53	6	500
1988	VA Big Game Booking	23	406,685	26	3	74	0	1,130
	TX Waterfowl	22	119,968	5	6	86	6	2,840
	Totals	283	1,907,668	203	1	704	6	12,581

*Covert operations represent only a fraction of FWS enforcement actions.
Source: DOI/Fish and Wildlife Service, Division of Law Enforcement, Information Sheet (1990).

Department of Commerce

The Office of Enforcement of the DOC/NOAA National Marine Fisheries Service (NMFS) enforces the provisions of the Magnuson Fishery Conservation and Management Act. In 1976 this act established a 200-mile fish conservation zone off the coast of the United States, thus quadrupling the area in which the agency enforces fish and shellfish regulations. Fishing out of season, landing in excess of catch limits, or harvesting undersized fish or shellfish are typical violations under the Magnuson Act. Illegal catches can be seized and sold, and in cases of unpaid penalties, fishing vessels can by confiscated.

The agency also enforces provisions of the Endangered Species Act, the Lacey Act, the Marine Mammal Protection Act, the Marine Protection Research and Sanctuaries Act, the Northern Pacific Halibut Act, the Tunas Convention Act, and the Agricultural Marketing Act, among others. In 1989 agents conducted investigations and built cases that led to 2,674 enforcement actions. Most violations were resolved through civil administrative procedures; however, 50 criminal cases were referred to the Department of Justice (Table 5-7). The NMFS Office of Enforcement detects and documents illegal fishing for salmon conducted on the high seas by driftnet vessels from Taiwan, Korea, and Japan.[18] Cases brought under the Lacey Act have resulted in jail sentences as high as 5 1/2 years and forfeitures in excess of $500,000. Enforcement personnel also use the Lacey Act to stop the interstate transportation and sale of unwholesome, unheathful molluscan shellfish harvested from polluted areas.

Department of Transportation

Since 1936, when Congress authorized the Coast Guard to enforce all federal laws on the high seas and on U.S. navigable waters, that agency has been the world's largest maritime police force. Officers may board foreign vessels in U.S. waters with permission, and they may board U.S. ships anywhere in the world. The Coast Guard enforces federal environmental laws affecting U.S. waters and beaches, including the Clean Water Act, the

Table 5-7.—Enforcement Actions Taken by the DOC/NOAA National Marine Fisheries Service, Office of Enforcement, 1984–89.

YEAR	CASES	COUNTS	ADMINISTRATIVE CASES	ADMINISTRATIVE COUNTS	CRIMINAL CASES	CATCHES SEIZED	FINES PAID*	PROPERTY FORFEITED	VESSELS SEIZED	AGENTS
							..... *thousand $*			
1984	2,012	3,061	1,653	2,393	61	68	3,527	219	7	96
1985	2,677	2,677	1,152	1,702	68	131	986	318	3	96
1986	2,137	3,389	1,228	2,043	116	233	1,212	588	4	96
1987	2,273	3,487	1,328	2,194	85	217	1,097	135	19	95
1988	2,539	3,975	1,767	2,722	56	283	1,284	468	8	95
1989	2,674	4,140	2,071	3,342	50	372	629	147	9	94

*Fines paid represent actual dollars collected, not what is owed or being paid under a settlement schedule.
Source: U.S. Department of Commerce, NOAA National Marine Fisheries Service, Office of Enforcement, Information Sheet (1990).

Ocean Dumping Act, the Endangered Species Act, and the Magnuson Fishery Conservation and Management Act. Within the U.S. 200-mile fish conservation zone, foreign vessels must obtain permission to fish, and the Coast Guard and NOAA enforce fishing regulations in the zone.

Congress responded to public concerns about wastes washing up on beaches by passing the 1988 Shore Protection Act, which the Coast Guard also enforces. The Clean Water Act designates the Coast Guard as the on-scene coordinator for responses to oil spills, and the Coast Guard National Strike Force has teams trained to respond to oil and chemical spills. Most Coast Guard enforcement involves administrative actions. Cases requiring civil and criminal actions are referred to the Department of Justice.

The Coast Guard also enforces the Hazardous Materials Transportation Act (HMTA) in conjunction with DOT administrations. Within the Department of Transportation, the Research and Special Programs Administration (RSPA) coordinates enforcement of HMTA. The act, passed in 1976, regulates the transport of hazardous materials on the nation's roads, railways, waters, and in the skies. Enforcement actions and surveillance to ensure compliance in each mode of transportation are conducted by the following DOT agencies: the Federal Highway Administration, the Federal Railroad Administration, the Coast Guard, and the Federal Aviation Administration.[19]

Most violations of HMTA are corrected by administrative actions, and in 1988 DOT agencies initiated 1,397 enforcement actions and collected $1.27 million in penalties under the act. Railroads paid the highest penalties, with an average fine of $9,793 (Table 5-8). The Customs Service in the Department of the Treasury cooperates with DOT and EPA in investigations of illegal imports or exports of hazardous materials.

Department of Labor

The Department of Labor's Occupational Safety and Health Administration (OSHA) was created by the Occupational Safety and Health (OSH) Act in 1970, the same year that CEQ, EPA, and NOAA were created. OSHA is primarily an enforcement

Table 5-8.—Civil Enforcement Actions Taken by Department of Transportation Agencies under the Hazardous Materials Transportation Act, 1987–88.

AGENCY	ACTIONS INITIATED	ACTIONS COMPLETED	LETTERS OF WARNING	PENALTIES	
				TOTAL	AVERAGE
				..... $	
Federal Aviation Administration					
1987	112	45	—	357,600	7,964
1988	112	37	—	279,500	7,554
Federal Highway Administration					
1987	N/A	65	—	290,300	4,466
1988	N/A	18	—	103,300	5,722
Federal Railroad Administration					
1987	43	43	—	565,800	13,158
1988	34	38	—	379,125	9,793
Research and Special Programs Administration					
1987	81	36	170	142,125	3,948
1988	120	98	161	392,900	4,009
U.S. Coast Guard					
1987	1,083	272	64	111,118	884
1988	1,131	321	120	119,687	823

Source: U.S. Department of Transportation, *Annual Report on Hazardous Materials Transportation—Calendar Year 1988*, DOT, Washington, DC (1989).

agency, and a majority of its employees work as inspectors. Federal regulations protect the safety and health of workers by regulating exposures to work hazards and toxic substances.

Violations of the OSH Act are subject to administrative penalties, but enforcement officials have found that criminal prosecutions may be the most effective enforcement tool.[20] For example, in 1985 three executives of a silver recovery firm were sentenced in Illinois state court to 25 years in prison, and each was fined $10,000 for contributing to the death of an employee in a cyanide explosion.

Criminal cases where an employer knowingly violates a regulation that results in an employee's death may be referred to state prosecutors or to the U.S. Department of Justice. In 1989 a U.S. court imposed the first federal incarceration under the OSH Act, in a case where a South Dakota employer was found guilty of negligence that led to the deaths of two employees.[21]

Department of Justice

Federal litigation, civil and criminal, is handled by the U.S. Department of Justice (DOJ), whose lawyers represent federal agencies when they sue and when they are sued. Within the DOJ Land and Natural Resources Division, a number of sections litigate environmental matters.

Environmental Enforcement Section

The largest section in the Land Division has a staff of 130 attorneys who handle civil suits in which the United States sues corporations and individuals for violations of environmental statutes. The staff, which has quadrupled in the past five years, handles the majority of federal civil environmental cases. Most civil cases do not go to trial but end in settlements through court-approved consent decrees. EPA is the section's major client, referring 95 percent of its cases.

In 1989 four statutes—Superfund, RCRA, the Clean Air Act, and the Clean Water Act—dominated a caseload of approximately 900 cases in the Environmental Enforcement Section. Superfund accounted for over half of those cases. Other cases con-

cerned violations of TSCA, the Safe Drinking Water Act, the Rivers and Harbors Act, the Ocean Dumping Act, and the Shore Protection Act.

In some cases, DOJ sued responsible parties for reimbursement after EPA cleaned up a hazardous waste site using Superfund monies. In other cases, DOJ sued to obtain a judicial consent decree when EPA was seeking to have responsible parties manage a cleanup. DOJ also sued to enforce EPA administrative orders that were not being followed. In some Superfund and Clean Water cases, when natural resources had been injured or destroyed by hazardous substances or oil spills, DOJ pursued claims for natural resource damages against responsible parties.

Environmental Crimes Section

Prosecution of environmental crimes is a major trend in environmental enforcement and a DOJ priority. The Environmental Crimes Section, first established as a unit in 1982, was elevated to section status in 1987. The staff has increased to 23 prosecutors who work in conjunction with U.S. attorneys on cases primarily referred by EPA but also by other federal agencies. Over the past six years, 432 guilty pleas or convictions have been obtained. Criminal fines totalled $26 million, and sentencing resulted in 98 years of confinement. The figures for pleas or convictions, fines, and confinement were highest in 1989 (see Table 5-9). The cases involved individuals, organizations, and federal facilities.

The prosecution for criminal violations of environmental laws at federal facilities is a recent development. In the past, because one federal agency cannot sue another, enforcement of federal environmental laws often was limited to EPA administrative actions, usually without penalty. The states were actually in a better legal position to force compliance with state environmental laws, but the situation is changing. In May 1989 three civilian managers employed by the U.S. Army at the Aberdeen Proving Ground in Maryland were convicted in federal court of illegal storage, treatment, and dumping of hazardous chemicals used to make chemical weapons. This case marked the first time that federal officials were held criminally liable for violating environmental laws.

Table 5-9.—Enforcement Actions Taken by the Department of Justice against Criminal Violations of Environmental Laws, Fiscal Years 1983–89.

FISCAL YEAR	INDICTMENTS	PLEAS/ CONVICTIONS	FINES IMPOSED	JAIL TERMS	ACTUAL CONFINEMENT
			$	..... *years/months/days*	
FY83	40	40	341,100	11yr	5yr
FY84	43	32	384,290	5yr/3mo	1yr/7mo
FY85	40	37	565,850	5yr/5mo	2yr/11mo
FY86	94 (+85*)	67 (+83*)	1,917,602	124yr/2mo/2da	31yr/4mo/12da
FY87	127	86	3,046,060	32yr/4mo/7da	14yr/9mo/22da
FY88	124	63	7,091,876	39yr/3mo/1da	8yr/3mo/7da
FY89	101	107	12,750,330	53yr/1mo	37yr/2mo
Total	569	432	26,097,108	268yr/8mo/10da	98yr/11mo/11da

*Pesticide investigation in Texas and Louisiana not included in total.
Source: U.S. Department of Justice, Environmental Crimes Section, Information Sheet (1989).

Overall, the number of criminal environmental cases being developed has increased sharply. In many of them, federal and state enforcers work together, and those cases declined by the federal government may be prosecuted by states with comparable environmental statutes. Cases declined for criminal prosecution may also be evaluated for a federal civil action.

Wildlife and Marine Resources Section

The caseload of this section includes civil and criminal prosecutions under natural resource laws, such as the Endangered Species Act, the Marine Mammal Protection Act, the Lacey Act, and the Magnuson Fisheries Conservation and Management Act. Section attorneys also defend federal agencies in civil actions brought against the government under environmental statutes.

Legal challenges often come from both sides of a case. For instance, the Fish and Wildlife Service (FWS) was sued in 1985 by environmentalists for allowing waterfowl hunters to use lead shot. After a federal court ruled against the agency, FWS changed its regulations to require the use of steel shot, and, in 1987, it was sued by a state fish and game commission on behalf of hunters. The Wildlife and Marine Resources Section represented FWS in both cases. Other clients include NOAA, the Army Corps of Engineers, the Forest Service, the Bureau of Reclamation, the Bureau of Land Management, and the Navy.

Section attorneys prosecute criminal cases and also advise U.S. attorneys and their assistants in the nation's 94 judicial districts. In the last decade, federal prosecutors have become more active in trying wildlife cases, but it is still difficult to convince some judges and juries that wildlife and rare plant violations are environmental crimes. Wildlife smuggling fines have increased, but they remain below those for smuggling drugs or guns.

Environmental Defense Section

When property owners challenge permit requirements in wetlands civil cases, the Environmental Defense Section represents the federal government. This section also sues violators of permit requirements. Information on wetlands violations comes from

the Army Corps of Engineers, EPA, the Fish and Wildlife Service, and state and local programs. Most wetlands cases handled by the section involve unpermitted violations and small acreages. Frequently, violators are required to remove illegal fill and restore habitat.

The Environmental Defense Section also defends federal regulatory agencies in suits filed by private citizens. The majority of such cases are filed against EPA for failing to meet enforcement deadlines.[22] The section also defends federal facilities sued by private citizens, citizens groups, or local or state governments for noncompliance with environmental laws. Most of the suits involve hazardous waste rather than air or water statutes.

Other Federal Enforcers

Each agency in the Executive Branch has an Office of Inspector General, whose staff may confront environmental violations in the course of other investigations. A number of federal agencies also enforce natural resource laws. For example, the Forest Service in the Department of Agriculture enforces environmental statutes such as the National Forest Management Act and the Wilderness Act. The National Park Service and the Bureau of Land Management in the Department of the Interior also enforce the Wilderness Act, and the Office of Surface Mining Reclamation and Enforcement enforces the Surface Mining Control and Reclamation Act. The Department of State handles international enforcement of U.S. environmental laws by means of treaties and diplomatic sanctions.

State and Local Enforcement

Despite the large number of enforcement actions taken by the federal government, most environmental enforcement is conducted by the states. In particular, Pennsylvania, New York, New Jersey, Ohio, and California have been active in pollution

control as long or longer than the federal government. Although many federal pollution-control laws stipulate states as primary enforcers, once their programs are federally approved, ultimate enforcement responsibility often is left with EPA. This statutory scheme requires coordination of state and federal enforcement programs to avoid conflicts or duplication of effort.

State and federal enforcers cooperate through such groups as the National Association of Attorneys General, which publishes the monthly *National Environmental Enforcement Journal* and sponsors enforcement symposia funded by EPA grants. Among the organizations representing state interests at the federal level are the State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials (STAPPA/ALAPCO), the Association of State and Interstate Water Pollution Control Administrators (ASIWPCA), and the Association of State and Territorial Solid Waste Management Officials (ASTSWMO). The National Governors Association and the National Association of District Attorneys are also active in shaping state environmental enforcement policies.

Each year, representatives from the states meet with EPA officials to negotiate enforcement agreements. Together they define such concepts as what makes a violation significant and what constitutes a timely and appropriate response. EPA grants are available to help fund state enforcement. States may request that EPA handle certain cases, but even without a request EPA may take direct action if a state response is untimely or lacking.

A primary goal of federal enforcers is to encourage state and local prosecution of environmental crime. The Department of Justice can not handle all the cases developed by federal agencies, and ultimately the question is not which level of government handles a case, but how quickly damage to the environment can be stopped and corrected. EPA and the National Association of Attorneys General are developing a database with sample criminal environmental statutes for use by states interested in drafting legislation. Working with the National Environmental Enforcement Council and the Federal Law Enforcement Training Center in Glynco, Georgia, they are encouraging program development in states that still have little or no criminal enforcement capability.

State Attorneys General and State Regulatory Agencies

In some states, attorneys general handle all environmental enforcement--administrative actions as well as civil and criminal. In other states, the attorney general may delegate enforcement to state regulatory agencies and assign an assistant attorney general to the agency. In yet other states, attorneys general do not have criminal enforcement jurisdiction, and criminal cases are handled by district attorneys and local prosecutors.

The varying enforcement structures in the different states coincide with a range of penalties for environmental violations (Tables 5-10 and 5-11). For example, in Alabama a knowing violation of a state clean air law can result in a prison term of one year at hard labor, while in New Hampshire a similar offense is punishable by seven years in jail, no hard labor specified. As of 1988 states with no air pollution statutes at all numbered 17. EPA-approved state programs are required to have state environmental statutes at least as strict as federal statutes, and some states have written even stricter laws.

States carry on the day-to-day operations of EPA-approved pollution control programs, including permitting, inspecting, and enforcement actions. A decline in state administrative actions over the past five years has corresponded with an increase in judicial cases, except for Clean Air Act violations where civil cases are down and administrative actions up (Table 5-5). With environmental priorities varying from state to state, enforcement programs range from the rudimentary to the highly sophisticated.

In Pennsylvania, a state with a long tradition of environmental enforcement, the Department of Environmental Resources is responsible for environmental law enforcement. Violations are identified through the reports of several hundred inspectors and through complaints from the community. An in-house legal staff with 75 attorneys handles civil cases. Criminal cases are referred to the state attorney general's office, where a Criminal Investigative Task Force pools the expertise of investigators and attorneys from the two departments.

Table 5-10.—Civil Penalties and Criminal Fines Authorized by the Environmental Laws of the 50 States and the District of Columbia Governing Hazardous Substance Control, 1987.

STATE	AGENCIES	PENALTIES & FINES		
		ADMINISTRATIVE	CIVIL	CRIMINAL
Alabama	Department of Environmental Management handles administrative enforcement and works with Alabama Attorney General on judicial enforcement.	$25,000/day $250,000 cap	$25,000/day no cap	$50,000–100,000/day and/or 1–20 yrs in jail
Alaska	Department of Environmental Conservation administers laws; Alaska Attorney General enforces them.	None	$100,000 + $10,000/day	$1,000–25,000/day 90 days–1 yr in jail
Arizona	Department of Environmental Quality administers laws; Arizona Attorney General enforces them.	None	$10,000/day	$150,000 and/or 2–5 yrs in jail
Arkansas	Department of Pollution Control and Ecology handles administrative and judicial enforcement.	$25,000/day	None	$1,000–10,000/day and/or 30 days to 5 yrs in jail
California	Department of Health Services, local agencies, State Water Resources Control Board, and nine Regional Water Quality Control Boards share administrative enforcement with California Attorney General. Judicial enforcement is shared by Attorney General, state district attorneys, city attorneys, and local prosecutors.	$1,000–10,000/day	$5,000–25,000/day	$500–250,000/day and/or 6 mon.–3 yrs in jail
Colorado	Department of Health administers laws; Colorado Attorney General enforces them.	None	$25,000/day	$750–50,000/day and/or 6 mon.–1 yr in jail
Connecticut	Department of Environmental Protection works with Connecticut Attorney General on administrative and judicial enforcement.	$25,000/day	$25,000/day	$25,000–250,000/day and/or 1–5 yrs in jail
Delaware	Department of Natural Resources and Environmental Control works with Delaware Attorney General on administrative and judicial enforcement.	$25,000/day	$25,000/day	$500–50,000/day and/or 1–2 yrs in jail

Table 5-10.—Civil Penalties and Criminal Fines Authorized by the Environmental Laws of the 50 States and the District of Columbia Governing Hazardous Substance Control, 1987 (cont.).

STATE	AGENCIES	PENALTIES & FINES		
		ADMINISTRATIVE	CIVIL	CRIMINAL
District of Columbia	Office of the Mayor administers laws; Corporation Counsel enforces them.	None	$25,000/day	$25,000/day and/or 1 yr in jail
Florida	Department of Environmental Regulation handles administrative and judicial enforcement.	None	$50,000/day	$50,000–100,000/day and/or 5–10 yrs in jail
Georgia	Department of Natural Resources administers laws; Georgia Attorney General enforces them.	$25,000/day	None	$50,000–250,000/day and/or 3–15 yrs in jail
Hawaii	Department of Health administers laws; Hawaii Attorney General enforces them.	$10,000/day	$10,000/day	$25,000–50,000/day and/or 1–2 yrs in jail
Idaho	Department of Health and Welfare administers laws; Idaho Attorney General and State District Attorneys handle judicial enforcement; no administrative enforcement.	None	$10,000/day	$10,000/day and/or 1 yr in jail
Illinois	State Environmental Protection Agency and a state Pollution Control Board administer laws; Illinois Attorney General enforces them.	$25,000/day	$25,000/day	$1,000–500,000/day and/or 1–14 yrs in jail
Indiana	Department of Environmental Management, a Solid Waste Management Board, a Water Pollution Control Board, and an Air Pollution Control Board administer laws; Indiana Attorney General enforces them.	$25,000/day	$25,000/day + $500/hr for violating an emergency order	$500–50,000/day and/or 6 months to 2 yrs in jail + 2 yrs for aggravated circumstances
Iowa	Department of Natural Resources handles administrative enforcement; Iowa Attorney General handles judicial enforcement.	$1,000/day	$10,000/day	$25,000–50,000/day and/or 1–2 yrs in jail

Kansas	Department of Health and Environment handles administrative enforcement and works with Kansas Attorney General on judicial enforcement.	$10,000/day	$10,000/day	$2,500–15,000/day and/or 1–20 yrs in jail
Kentucky	Natural Resources and Environmental Protection Cabinet handles administrative and judicial enforcement.	None	$25,000/day	$25,000/day and/or 1–5 yrs in jail
Louisiana	Department of Environmental Quality handles administrative enforcement; Louisiana Attorney General handles judicial enforcement.	$25,000–50,000/day	$25,000–50,000/day	$100,000–250,000/day and/or 10–15 yrs in jail
Maine	Department of Environmental Protection administers laws; Maine Attorney General enforces them.	None	$25,000/day	$1,000–50,000/day and/or 6 mon.–5 yrs in jail, plus twice pecuniary gain
Maryland	Department of the Environment works with Maryland Attorney General and State District Attorneys on administrative and judicial enforcement.	$1,000/day $50,000 cap	$10,000/day	$10,000–100,000/day and/or 6 mon.–5 yrs in jail
Massachusetts	Department of Environmental Quality Engineering handles administrative enforcement; Massachusetts Attorney General handles judicial enforcement.	$1,000–25,000/day	$25,000/day	$25,000–100,000/day and/or 2–20 yrs in jail
Michigan	Department of Natural Resources administers laws; Michigan Attorney General enforces them.	None	$25,000/day	$25,000–250,000/day and/or 1–2 yrs in jail, 5 yrs for extreme indifference
Minnesota	Pollution Control Agency administers laws; Minnesota Attorney General enforces them.	$10,000/inspection; waived if corrected within 30 days	$25,000/day	$100–100,000 and/or 90 days–10 yrs in jail
Mississippi	Department of Natural Resources works with Mississippi Attorney General on administrative and judicial enforcement.	$25,000/day	None	$25,000/day and/or 1 yr in jail
Missouri	Department of Natural Resources administers laws; Missouri Attorney General enforces them.	None	$10,000/day	$2,500–50,000/day and/or 1–10 yrs in jail

Table 5-10.—Civil Penalties and Criminal Fines Authorized by the Environmental Laws of the 50 States and the District of Columbia Governing Hazardous Substance Control, 1987 (cont.).

STATE	AGENCIES	PENALTIES & FINES		
		ADMINISTRATIVE	CIVIL	CRIMINAL
Montana	Department of Health and Consolidated Laboratories handles administrative and judicial enforcement.	None	$10,000/day	$10,000–20,000/day and/or 6 mon.–1 yr in jail
Nebraska	Department of Environmental Control handles administrative enforcement; Nebraska Attorney General and State District Attorneys handle judicial cases.	None	$10,000/day	$10,000/day and/or 6 months in jail
Nevada	Department of Conservation and Natural Resources works with Nevada Attorney General on administrative and judicial enforcement.	None	$10,000/day	$10,000–50,000/day and/or 1–6 yrs in jail
New Hampshire	Department of Environmental Services administers laws; New Hampshire Attorney General enforces them.	None	$50,000/day	$1,000–50,000/day and/or 1–7 yrs in jail
New Jersey	Department of Environmental Protection administers laws; New Jersey Attorney General enforces them.	$25,000 per violation + $2,500/day	$25,000–50,000/day	$7,500–50,000/day and/or 18 mon.–5 yrs in jail plus restitution for damages
New Mexico	Department of Health and the Environment handles administrative and judicial enforcement.	$10,000/day	$10,000/day	$500–100,000/day and/or 6 mon.–15 yrs in jail
New York	Department of Environmental Conservation handles administrative enforcement; New York Attorney General handles judicial enforcement.	$25,000–50,000/day	$25,000–50,000/day	$10,000–200,000/day and/or 90 days–15 yrs in jail; plus 2× economic gain; plus costs of disposal, abatement, and restoration
North Carolina	Department of Human Resources and Department of Natural Resources and Community Development administer laws; North Carolina Attorney General enforces them.	$10,000/day	None	$10,000 and/or 6 mon. to 2 yrs in jail

North Dakota	Department of Health and Consolidate Laboratories works with state Attorney General on administrative and judicial enforcement.	None	$25,000/day	$25,000–50,000/day and/or 1–2 yrs in jail
Ohio	Ohio Environmental Protection Agency administers laws; Ohio Attorney General enforces them.	None	$10,000/day	$10,000–50,000 and/or 2–4 yrs in jail
Oklahoma	State Department of Health handles administrative enforcement; State District Attorneys handle judicial enforcement.	$10,000/day	$10,000/day	$10,000/day and/or 6 mon. in jail
Oregon	Department of Environmental Quality administers laws; Oregon Attorney General enforces them.	$10,000/day	None	$10,000/day and/or 1 yr in jail
Pennsylvania	Department of Environmental Resources handles administrative enforcement and works with Pennsylvania Attorney General on judicial enforcement.	$25,000/day	$25,000/day	$10,000–500,000/day and/or 2–20 yrs in jail
Rhode Island	Department of Environmental Management handles administrative enforcement and works with Rhode Island Attorney General on judicial enforcement.	$10,000/day	$10,000/day	$500–10,000/day and/or 5 yrs plus costs of restoration
South Carolina	Department of Health and Environmental Control handles adminstrative and judicial enforcement.	$25,000/day	$25,000/day	$25,000–50,000/day and/or 1–2 yrs in jail
South Dakota	Department of Water and Natural Resources administers laws; South Dakota Attorney General enforces them.	None	$10,000/day	$10,000/day and/or 10 yrs in jail
Tennessee	Department of Health and Environment, Solid Waste Disposal Board, and Water Quality Control Board handle administrative enforcement and work with Tennessee Attorney General on judicial enforcement.	$10,000/day	None	$10,000–50,000/day and/or 11 mon., 29 days to 2 yrs in jail

Table 5-10.—Civil Penalties and Criminal Fines Authorized by the Environmental Laws of the 50 States and the District of Columbia Governing Hazardous Substance Control, 1987 (cont.).

STATE	AGENCIES	PENALTIES & FINES		
		ADMINISTRATIVE	CIVIL	CRIMINAL
Texas	Texas Water Commission handles administrative enforcement; Texas Attorney General handles judicial enforcement.	$10,000/day	$25,000/day	$50,000–250,000/day and/or 2–15 yrs in jail
Utah	Department of Health administers laws; Utah Attorney General enforces them.	None	$10,000/day	$15,000–25,000/day
Vermont	Agency of Natural Resources administers laws; Vermont Attorney General handles judicial enforcement; no administrative enforcement.	None	$10,000/day	$25,000/day and/or 6 mon. in jail
Virginia	Department of Waste Management, Virginia Waste Management Board, and State Water Control Board administer laws; Virginia Attorney General enforces them.	None	$10,000/day	$1,000–10,000/day and/or 1 yr in jail
Washington	Department of Ecology works with Washington Attorney General on administrative and judicial enforcement.	$10,000/day	None	$10,000/day and/or 1 yr in jail
West Virginia	Department of Natural Resources administers laws; West Virginia Attorney General enforces them.	None	$25,000/day	$25,000–250,000/day and/or 1–4 yrs in jail
Wisconsin	Department of Natural Resources handles administrative enforcement; Wisconsin Attorney General handles judicial enforcement.	None	$25,000/day	$25,000–50,000/day and/or 1–2 yrs in jail
Wyoming	Department of Environmental Quality administers laws; Wyoming Attorney General enforces them.	None	$10,000/day	$10,000–50,000/day and/or 1–2 yrs in jail

Source: Environmental Law Institute for EPA Office of Waste Programs Enforcement, RCRA Enforcement Division, "State Hazardous Waste Enforcement Study," 2 volumes, ELI, Washington, DC (1987).

Table 5-11.—Criminal Fines Authorized by the Environmental Laws of the 50 States Governing Water and Air Pollution, 1988.

STATE	WATER POLLUTION	AIR POLLUTION
Alabama	Willful or negligent violation: $2,500–25,000/day and/or 1 year in jail. Second conviction: $5,000–$50,000 and/or 2 years in jail. Knowing false statement: $10,000 and/or 6 months in jail.	Knowing violation: 1 year of hard labor.
Alaska	Willful violation: $25,000 and/or 1 year in jail and costs of prosecution. False statement: $25,000 and/or 1 year in jail.	Willful violation: $25,000 and/or 1 year in jail. False statement: $25,000 and/or 1 year in jail.
Arizona	Knowing violation or criminal negligence: up to $150,000 and/or 1.87–2.5 years in jail. Extreme indifference for human life: $150,000 and/or 14 years in jail. Corporations: $1 million.	None.
Arkansas	When violator remains in state, misdemeanor: $10,000 and/or 1 year in jail. When violator flees state, felony: $10,000 and/or 5 years in jail.	Same as for water pollution.
California	Discharge of waste or failure to furnish reports, misdemeanor: $1,000 per day and/or 6 months in jail. Subject to civil penalties.	Misdemeanor: up to $1,000 and/or 6 months in jail.
Colorado	Negligent or reckless violation: up to $12,500. Knowing or intentional violation: $25,000. Knowing false statement: up to $10,000 and/or 6 months in jail.	None.
Connecticut	Willful or criminally negligent violation: $25,000/day and/or 1 year in jail. Second offense: $50,000 and/or 2 years. False statement or failure to report: $10,000 and/or 6 months in jail.	None.
Delaware	Willful or negligent violation: $2,500–25,000/day. Knowing false statement: $500–5,000 per day and/or up to 6 months in jail. Failure to report: $500–5,000 and/or 6 months in jail.	Willful or negligent violation: $2,500–$25,000/day. Knowing false statement: $500–5,000/day and/or 6 months in jail. Failure to report: $500–5,000 and/or 6 months in jail.
Florida	Willful or negligent violation: $2,500–25,000 and/or 1 year in jail. False statement: Up to $10,000 and/or 6 months in jail. Failure to obtain permit: $2,500–25,000 and/or 1 year in jail.	Same as for water pollution.

Table 5-11.—Criminal Fines Authorized by the Environmental Laws of the 50 States Governing Water and Air Pollution, 1988 (cont.)

STATE	WATER POLLUTION	AIR POLLUTION
Georgia	Misdemeanor: $2,500–25,000/day and/or 1 year in jail. False statement felony: $10,000 and/or 2 years in jail. Second conviction: $20,000/day and/or 4 years in jail. Felony: $15,000–150,000/day and/or 2 years in jail. Second conviction: $100,000/day and/or 4 years in jail. Knowing endangerment: up to $250,000 and/or 15 years in jail.	None.
Hawaii	Willful or negligent violation: $25,000–100,000/day and/or not more than 5 years in jail.	None.
Idaho	None.	Willful or negligent violation: up to $10,000/day or $1,000 for continuing violations whichever is greater.
Illinois	Felony: $25,000/day and/or up to 3 years in jail. Negligent violation: $10,000. False statement: up to $10,000 and/or 1 year in jail.	None.
Indiana	Intentional, reckless, or negligent violation: $2,500–25,000 and/or 1 year in jail. Second conviction: $50,000 and/or 2 years in jail. False statement: $10,000 and/or six months in jail.	Same as for water pollution.
Iowa	Willful or negligent violation: $10,000/day. Second conviction: $20,000. Knowing false statement: $10,000/day and/or 6 months in jail.	None.
Kansas	Willful or negligent violation: $25–10,000/day. Knowing false statement: $25–10,000/day.	None.
Kentucky	Knowing or criminally negligent violation: $1,000–15,000/day and/or up to 1 year in jail.	Same as for water pollution.
Louisiana	Felony: $100,000/day, costs of prosecution, and/or 10 years in jail. Misdemeanor: $25,000/day, costs of prosecution, and/or 1 year in jail.	Same as for water pollution.
Maine	Criminal violation: $25,000 and/or 5 years in jail. False statement: $10,000/day and/or 6 months in jail.	Same as for water pollution.

Maryland	Misdemeanor violation: up to $25,000 and/or 1 year in jail. False statement: up to $10,000 and/or 6 months in jail.	None.
Massachusetts	Direct or indirect violation: $2,500–25,000/day/violation and/or 1 year in jail. False statement: $2,500–25,000/day/violation and/or 1 year in jail.	Misdemeanor: up to $25,000 and/or up to 1 year in jail.
Michigan	Misdemeanor: $2,500–25,000. Second conviction: $50,000	Misdemeanor: up to $10,000 and an additional $2,000/day if violation continues.
Minnesota	Misdeanor: up to $700/violation and/or 90 days in jail; willful: $2,500; negligent: $300; up to $40,000/day and/or 1 year in jail; subsequent violation: $50,000/day and/or 2 years in jail. False statements: up to $20,000/day and/or 6 months in jail.	False statement: up to $20,000/day and/or 6 months in jail. Misdemeanor: $700/day/violation and/or 3 months in jail.
Mississippi	Violation: $2,500–25,000.	Same as for water pollution.
Missouri	Willful or negligent violation: $2,500–25,000 and/or 1 year in jail. Second conviction: $50,000 and/or 2 years in jail.	None.
Montana	False statements: $10,000/day and/or 6 months in jail. Willful or negligent offense: $25,000/day and/or 1 year in jail.	$1,000 and/or 6 months in jail.
Nebraska	False statements: up to $5,000/day. Misdemeanor: up to $5,000/day and/or 6 months in jail.	Misdemeanor: $5,000/day.
Nevada	Gross misdemeanor: up to $25,000 and/or 1 year in jail. Second conviction felony: up to $50,000 and/or 6 months in jail. False statements: $10,000 and/or 1 year in jail.	None.
New Hampshire	Willful or negligent violation: up to $25,000. False statements: up to $25,000/day and/or 6 months in jail. Misdemeanor if natural person; felony if any other person, up to $500.	Misdemeanor: $10,000 and/or 1 year in jail. Felony if an organization: $10,000 and/or 7 years in jail.
New Jersey	$5,000–50,000/day and/or 1 year in jail. Second conviction: $10,000–$100,000/day and/or 2 years in jail. False statements: $20,000 and/or 6 months in jail.	None.
New Mexico	Misdemeanor: $300–10,000/day and/or 1 year in jail.	None.
New York	Misdemeanor: $2,500–25,000/day and/or 1 year in jail. Second conviction: $50,000 and/or 2 years in jail.	Misdemeanor: $250–10,000/day and/or 1 year in jail.

Table 5-11.—Criminal Fines Authorized by the Environmental Laws of the 50 States Governing Water and Air Pollution, 1988 (cont.)

STATE	WATER POLLUTION	AIR POLLUTION
North Carolina	False statements: $10,000/day and/or 6 months in jail. Misdemeanor: up to $15,000/day/violation with cumulative total of $200,000/month and/or 6 months in jail.	Misdemeanor: up to $15,000/day with cumulative total of $200,000/month and/or 6 months in jail. False statements: $10,000/day and/or 6 months in jail.
North Dakota	Willful violation: $25,000/day and/or 1 year in jail. Second conviction: $50,000 and/or 2 years in jail. Knowing false statement: $10,000 and/or 6 months in jail.	Willful violation: up to $25,000/day and/or 1 year in jail. Second conviction: $50,000 and/or 2 years in jail. Knowing false statement: $10,000 and/or 6 months in jail.
Ohio	$25,000 and/or 1 year in jail.	$25,000/day and/or 1 year in jail.
Oklahoma	Failure to have permit: $500 and/or 6 months in jail. Violation of code: $200 and/or 30 days in jail. False information: $200. Failure to file a certificate: $200. Wastewater violation: $200–10,000 and/or 6 months in jail. Knowing false statement: up to $5,000/violation.	Misdemeanor: $500 and/or 1 year in jail.
Oregon	Misdemeanor: up to $25,000 and/or up to 1 year in jail.	Misdemeanor: up to $2,500 and/or up to 1 year in jail.
Pennsylvania	Summary offense: $100–10,000 and/or 3 months in jail. Willful or negligent violation: $2,500–25,000 and/or 1 year in jail. Willful or negligent violation within 2 years of first conviction: $2,500–50,000 and/or 2 years in jail.	Summary offense: $100–1,000 and/or up to 30 days in jail, if in default of payment of fine.
Rhode Island	Up to $10,000 and/or 30 days in jail. Knowing false statement: $5,000/violation and/or 30 days in jail.	Up to $500 and/or 30 days in jail.
South Carolina	Willful or negligent violation: $500–25,000 and/or 2 years in jail. Knowing false statement: $500–$25,000 and/or 2 years in jail. Each day of noncompliance is a separate violation.	Willful or negligent violation: $500–25,000 and/or 2 years in jail. Knowing false statement: $500–25,000 and/or 2 years in jail. Each day of noncompliance is a separate violation.
South Dakota	Misdemeanor: $10,000 and/or 1 year in jail. Knowing false statement: $10,000 and/or 1 year in jail.	None.
Tennessee	Misdemeanor: $50–25,000/day. Felony: $25,000 and/or 2 years in jail.	Misdemeanor: $50–1,000/day.

Texas	Waste discharge: $10–10,000. Willful or negligent point-source waste discharge: up to $25,000. Knowing false statement: up to $25,000. Violation of permit: $10–$10,000.	None.
Utah	Willful or negligent violation: up to $25,000/day. Second conviction: $50,000. Knowing false statement: up to $10,000 and/or 6 months in jail.	Knowing violation: $25,000. Second violation: $50,000. Willful failure to furnish information: $2,500 and/or 1 year in jail.
Vermont	Noncompliance with permit: up to $25,000 and/or 6 months in jail. Knowing false statement: up to $10,000 and/or 6 months in jail.	Up to $20,000.
Virginia	$100–25,000.	Misdemeanor: $1,000/violation.
Washington	Crime: up to $10,000 and/or 1 year in county jail and costs of prosecution.	Gross misdemeanor: $100–1,000.
West Virginia	Willful or negligent violation: $2,500–25,000/day and/or 1 year in jail. Intentional misrepresentation: $1,000–10,000 and/or 6 months in jail. Failure to obtain permit: $100–1,000 and/or 6 months in jail.	None.
Wisconsin	Willful or negligent violation: $25,000/day and/or 6 months in jail. Second conviction: $50,000/day and/or 1 year in jail. Knowing false statment: $10,000/day and/or 6 months in jail.	None.
Wyoming	Willful or negligent violation: up to $25,000 and/or 1 year in jail. Second conviction: $50,000 and/or 2 years in jail. Knowing false statement: $10,000 and/or 1 year in jail.	Willful or negligent violation: up to $25,000 and/or 1 year in jail. Second conviction: $50,000 and/or 2 years in jail. Knowing false statment: $10,000 and/or 1 year in jail.

Source: DeCicco, J., and E. Bonanno, "A comparative analysis of the criminal environmental laws of the fifty states: the need for statutory uniformity as a catalyst for effective enforcement of existing and proposed laws," *The Criminal Justice Quarterly* (1988), 9(4):235–294.

Pennsylvania's major environmental statutes—the Solid Waste Management Act and the Clean Streams Act—are comparable to federal statutes. EPA handles perhaps 50 cases per year in the state, while the Pennsylvania Department of Environmental Resources handles some 2,000 violations.[23]

Other states with well-developed enforcement programs include Minnesota, which in 1983 enacted an Environmental Response and Liability Act establishing a strict liability standard for hazardous waste cleanups and for personal injuries resulting from toxic exposure. Within two years, 17 consent decrees had been signed covering cleanups costing $25 million. Massachusetts and several other states have passed superlien acts that allow states to recover cleanup costs by placing a lien on a site and, in some states, on other property owned by responsible parties. State hazardous waste superliens are given priority over pre-existing liens; federal superliens are not.

New Jersey's enforcement program began in the early 1980s, when members of the Northeast Hazardous Waste Project spearheaded the formation of state criminal enforcement strike forces to combat the illegal disposal of hazardous wastes. Organized crime was represented among the offenders, and the situation was not new.

In the late 1970s suspected organized crime elements took over a New Jersey incinerator and began stockpiling hazardous wastes.[24] Drums of toxic chemicals, explosives, flammable/ ignitible materials, and caustic agents were piled indiscriminately. No treatment or disposal processes were applied. In April 1980 the facility, along with about 50,000 drums of hazardous wastes, went up in flames, sending clouds of noxious fumes and particulates into the air. A public health emergency was averted when winds carried the toxic smoke and airborne pollutants away from nearby Staten Island, which was facing evacuation. The owners of the incinerator walked away with several million dollars, while the United States spent over $26 million to clean up the site. Superfund was enacted shortly after the New Jersey incinerator fire, and since then federal and state enforcers have refined techniques for recovering the cost of cleanup from potentially responsible parties.

Today the New Jersey Environmental Cleanup Responsibility Act requires private parties to notify the state prior to the sale of certain industrial property. Owners must submit a

declaration that no hazardous wastes have been discharged on the site, or, as an alternative, they may submit a cleanup plan. By 1987 the law had produced over 250 private party cleanups.[25]

In neighboring New York, legislators amended the State Criminal Procedure Law in 1983 to permit electronic eavesdropping in hazardous waste investigations. The New York Division of Criminal Justice Services cited the eavesdropping amendment as "the first official indicator of the state's recognition of organized crime involvement in hazardous waste disposal."[26]

New York is among a number of states that have upgraded criminal statutes and developed criminal enforcement units (see Table 5-12 for data on New York enforcement). Within the New York Department of Law, which is the attorney general's office, the Environmental Protection Bureau has an Environmental Crime Unit that handled 27 hazardous-waste cases in 1988. Several defendants agreed to consent orders, and several cases were resolved with conditional discharges. Penalties totaled $1.2 million, and sentences included intermittent imprisonment (weekends in jail for one year), jail terms, and probation with community service. In one illegal dumping case, the defendant was required to remove all waste—construction, non-construction, and demolition debris—from the site, deposit it in a licensed sanitary landfill, and pay for wellwater testing.

The New York Department of Environmental Conservation (EnCon) has a Division of Law Enforcement with a Bureau of Environmental Conservation Investigations. In 1988 the Bureau, which is composed of uniformed police officers, closed 93 hazardous waste cases. Monies collected from criminal fines, civil penalties, and administrative consent orders totaled $1.1 million. The majority of violators were corporations.

The New York Division of Criminal Justice Services also tracks individuals convicted of hazardous waste crimes. Between 1986 and 1988, the number of individuals convicted for the most serious violations was 56.[27]

Other states are just beginning to develop enforcement programs. For example, the attorney general of Kentucky recently announced formation of an Environmental Crime Workgroup to identify, investigate, and prosecute environmental violations. In addition to the State Attorney General's Office, other workgroup members are the State Natural Resources and En-

Table 5-12.—Judicial Enforcement Actions Taken against Hazardous Waste and Waste Disposal Violations by State and County Agencies in New York, 1988.

Agency	CASES	CONVICTIONS		SENTENCING			
		INDIVIDUALS	CORPORATIONS	JAIL	PROBATION	CONSENT ORDERS	PENALTIES
				terms	*hours*		*$*
Kings County District Attorney's Office							
—Environmental Crimes Bureau	14	5	9	2	610	—	282,718
Suffolk County District Attorney's Office							
—Environmental Crimes Unit	24	2	10	1	—	12	91,800
State Department of Law (State Attorney General)							
—Environmental Protection Bureau	31	22	12	2	yes	yes	1,151,900
State Department of Environmental Conservation (EnCon)							
—Bureau of Environmental Conservation Investigations (Uniformed police make arrests.)	93	16	77	—	—	yes	1,054,011
—Division of Environmental Enforcement (Legal experts develop evidence.)	2	—	2	—	—	yes	2,500
New York State Police							
—Hazardous Materials Unit	874*						
—Motor Carrier Safety Assistance Program Unit	649*						

*Violations of state hazardous waste transport laws by vehicles stopped, inspected, and ticketed on New York highways.
Source: New York Division of Criminal Justice Services, *1988 Crime and Justice Annual Report*, New York State, Albany (1989), pages 217–231.

vironmental Protection Cabinet, the Kentucky State Police, the U.S. Attorney's Office, EPA, and the FBI. As part of the effort, the State Attorney General will ask the legislature for funding to establish an Environmental Prosecutions Unit.[28]

District Attorneys and Local Prosecutors

Local prosecutors have tended to leave enforcement of environmental laws up to state and federal enforcers. However, this situation is changing as local and state police and firefighters receive training in environmental crime investigation. As local investigators gain experience in gathering environmental evidence, local prosecutors have begun to accept environmental cases that they can take to trial.[29]

Among the states with active local enforcement programs, California involves multiple local and state agencies in developing and prosecuting individual cases. For example, in a case prosecuted by the Los Angeles District Attorney, the defendants were charged with 27 misdemeanor counts, each for a different week of knowingly storing hazardous wastes without a permit; 27 misdemeanor counts for illegal disposing of wastes; 19 misdemeanor counts for transporting wastes to an unpermitted facility; 7 misdemeanor counts for willfully discharging wastes; and 7 misdemeanor counts for discharging and depositing wastes. The defendants pled no contest and were sentenced to serve 15-30 days of intermittent imprisonment and pay fines of $150,000 plus $150,000 in investigative and prosecutorial costs. The costs had been incurred by six different agencies.[30]

In New York, local prosecutors also are handling hazardous waste violations. The King's County District Attorney's Office created an Environmental Crimes Bureau in 1986, and in 1988 the Bureau obtained 14 hazardous waste convictions. Sentences for the defendants--five individuals and nine corporations--consisted of two 4-year jail terms, 610 hours of community service, and $282,718 in fines and forfeitures. In Suffolk County, New York, an Environmental Crimes Unit was established in 1984 in the District Attorney's Office. In 1988 the unit investigated 24 cases and obtained 12 convictions. Charges included felonies,

misdemeanors, and violations of the Suffolk County Environmental Code. Two individuals and 10 corporations paid fines of $91,800. All convicted parties were required to clean up discharged pollutants.

Enforcement Tools Today

Over the past decade, amendments to state and federal environmental laws have given enforcers more and better tools. Recent additions included full arrest and firearm powers for EPA's criminal investigators and uniform sentencing guidelines.

Compliance Monitoring

Periodic checks to determine if facilities are in compliance with regulations serve as a deterrent to violations of environmental law. The primary method for collecting compliance data is the facility inspection, during which local, state, or federal inspectors review records, take samples, and observe operations. If federal criminal violations are suspected, criminal investigators from such agencies as EPA and the FBI are called in. If the interstate transport of hazardous waste is involved, DOT investigators may participate. In some cases, a search warrant is needed to gain access.

From inspections and from the reports required of permitted facilities, regulatory agencies can determine if an operation is in compliance with environmental regulations. Facilities in noncompliance face an administrative, civil, or criminal enforcement action.

Investigations

Environmental enforcement depends on the work of environmental investigators located in a number of federal, state, and local agencies.

EPA/National Enforcement Investigations Center (NEIC)

In 1989 the EPA had 49 criminal investigators trained in the high-risk job of identifying violations and collecting evidence for prosecutions. EPA criminal investigators were granted permanent law enforcement powers to arrest and carry weapons by the 1988 Medical Waste Tracking Act. A rider to the act granted them full enforcement powers while investigating crimes under all environmental laws.[31] Previously, they had been sworn in annually as special deputy U.S. marshalls.

EPA investigators are headquartered at the agency's National Enforcement Investigations Center (NEIC) in Denver, Colorado, and are located in 10 cities around the country. NEIC, the technical arm of the EPA Office of Enforcement and Compliance Monitoring, was first established in 1970, pre-EPA, to train water pollution enforcement staff. Today laboratory scientists, investigators, and engineers work at the center collecting and analyzing evidence for EPA cases.

NEIC has trained and sent physical science, engineering, and laser technicians to gather evidence at some of the major pollution incidents in recent years. NEIC investigators measured dioxin levels at Times Beach, Missouri, and collected samples of carcinogenic compounds at Love Canal in Niagara Falls, New York. Technicians, described by news reporters as "sludgebusters" and "enviro-cops,"[32] often are outfitted with oxygen masks, moonsuits, and sophisticated pollution-detection devices. NEIC has developed a mobile laser gun called Lidar (Light Detection And Ranging) that combines laser and radar technology to monitor smokestacks suspected of illegal emis-

sions. In addition to the center in Denver, 24 other EPA research facilities in 16 states assist with investigations and evidence.

NEIC coordinates four regional environmental enforcement organizations: the Northeast Hazardous Waste Project in Trenton, New Jersey; the Midwest Environmental Enforcement Association in Elgin, Illinois; the Southern Environmental Enforcement Network in Montgomery, Alabama; and the Western States Hazardous Waste Project in Phoenix, Arizona. The Midwest group has its office in the headquarters of the Illinois state police, while the other three are located in offices of the state attorneys general. The groups meet regularly and, by means of a computerized information exchange, share data on environmental violations in different states. NEIC assists the groups in conducting environmental training programs for state and local investigators and prosecutors.

DOJ/Federal Bureau of Investigation (FBI)

In 1982 the FBI and EPA signed a Memorandum of Understanding enabling the agencies to conduct joint investigations. That agreement marked a milestone in the evolving concept of environmental crime. The FBI now ranks environmental crimes as priority investigations, and conducts joint FBI/EPA investigations as well as independent initiatives. EPA investigators contribute the technical expertise to gather evidence of environmental crimes, while the FBI lends the traditional law-enforcement skills of 10,000 agents and a renowned forensics laboratory. Between 1986 and 1989 over 1,000 federal, state, and local enforcement officers attended FBI training courses on how to investigate environmental crimes.

In 1989 the FBI investigated 245 environmental crimes, devoting 28 agent-years to the cases. Toxic waste violations accounted for the majority of cases. Special Agents investigated violations ranging from illegal storage, transport, and disposal by corporations and federal facilities to the corruption of public officials and infiltration of the disposal industry by organized crime.[33]

The investigation of federal facilities is a recent development. In the past, national security concerns limited the access

of investigators concerned about possible environmental violations at some DOD and DOE installations. Today the situation is changing. In June 1989 a team of FBI, EPA, and state environmental investigators executed a search warrant at the gates of the Rocky Flats Plant, outside Denver. The plant is a DOE installation that manufactures nuclear components, non-nuclear assemblies, and hardware for nuclear weapons. Numerous violations of environmental laws were suspected. During an earlier inspection, volatile organic vapors at a groundwater monitoring well caused the inspectors to wear protective suits and respirators.

Another recent development is the investigation of environmental crimes under both environmental laws and the Racketeering Influenced Corrupt Organization Act (RICO), first passed in 1970. For example, cooperative investigations by the FBI, EPA, and the DOJ Organized Crime Strike Force led in 1989 to the prosecution of two individuals in Connecticut for RICO, RCRA, and CERCLA violations for the illegal disposal of mercury.[34]

FBI agents increasingly uncover elaborate methods of concealing criminal disposal of wastes. In response, they now employ a number of sophisticated investigative techniques, such as:

- Closed circuit television surveillance,
- Aerial surveillance,
- Infrared photography,
- Undercover operations,
- Informants,
- Toxicological examinations,
- Consensual monitoring,
- Records review by accounting technicians,
- Microcomputers for case management, and
- Search warrants and the use of heavy construction equipment for gathering evidence.

DOI/National Fish and Wildlife Forensics Laboratory

In 1989 the U.S. government dedicated a new $3.5 million National Fish and Wildlife Forensics Laboratory in Ashland, Oregon. The first of its kind in the nation, the laboratory can identify species of wildlife parts and products seized as evidence. Like a police lab, it can match suspect, victim, and crime scene through the examination of physical evidence. Forensics experts use scanning electron microscopes to identify a species from hair, fur, leather, hides, feathers, tusks, claws, and teeth.

Species identity is crucial in enforcement cases. Although two species may be similar, the importation of one may be legal, while the other is prohibited. A serology section in the forensics laboratory uses advanced techniques to identify species from blood and tissue samples. A criminalistics section performs instrument analysis on such specimens as carved ivory, powdered rhino horn, sea turtle oil, shell products, and wildlife poisons. The FWS forensics laboratory offers technical assistance to federal, state, and municipal enforcement agencies. After investigators obtain the evidence needed to crack wildlife crime rings, sometimes at great risk, the forensics laboratory makes sure the evidence can be used in court.[35]

DOC/NOAA National Marine Fisheries Service, On-Site Observers

At sea where compliance with environmental laws is difficult to check, the Department of Commerce (DOC) uses on-site observers who work under contract with the National Marine Fisheries Service. They accompany fishing vessels and collect information needed to judge whether the vessels are in compliance with agreements and regulations. Since 1983 the Magnuson Act has required that all foreign vessels fishing off the U.S. coast have a fisheries observer on board. Today many domestic vessels must also carry an observer. Under the Marine Mammal Protection Act, observers are required on U.S. tuna purse-seine vessels

and on other U.S. vessels whose operations in fisheries result in the death of marine mammals. The courts have balanced the intrusiveness of observers against the pervasively regulated aspect of the industry, and found them to be acceptable.

State and Local Investigators

A number of states have special units that carry out environmental investigations. For example, the New York Department of Environmental Conservation has a Division of Environmental Enforcement with a staff of attorneys, engineers, geologists, and chemists who provide legal and technical support for federal, state, and county enforcers. They evaluate investigations for legal sufficiency, conduct legal research, draft search warrants, sample and analyze evidence, and assist investigators in developing cases for referral. On occasion, division attorneys have been deputized to handle prosecutions.

In states that do not have special environmental enforcement units, state/federal cooperative efforts are underway to train city police, county sheriffs, and state troopers in how to investigate an environmental crime. Local law enforcement officers are likely to encounter illegal dumpers or notice discharge pipes feeding waste into a stream. They often are the first to see or hear about drums of chemicals abandoned in warehouses or fields, and they confront environmental crimes in the course of investigating other crimes. For example, when exercising search warrants on illegal methamphetamine laboratories, police have found containers of hazardous chemicals that threaten the safety of the investigators and the neighborhood. Often the buildings and grounds around illegal laboratories are contaminated and require cleanup.[36]

Consequently, training programs for state and local police have been expanded to include environmental enforcement, and officers also attend federal training programs. In addition to FBI environmental training programs, four tuition-free EPA training programs in hazardous waste investigations are held each year at the Federal Law Enforcement Training Center in Georgia.

Some states already have "enviro-cops" on duty. For instance, in New York two units of the state police handle hazard-

ous materials transport violations. A Hazardous Materials Unit has 16 uniformed state troopers authorized to stop and inspect any vehicle suspected of carrying hazardous materials. In 1988 officers inspected over 3,000 vehicles carrying hazardous materials on New York highways. They found 25 percent with safety violations serious enough to remove them from service.

The New York State Police Motor Carrier Safety Assistance Program Unit, also composed of 16 uniformed state troopers, works with the State Department of Transportation to monitor hazardous materials transport. In 1988 officers inspected over 5,000 trucks and issued 649 tickets for hazardous materials violations.[37]

Administrative Actions

Environmental enforcers rely primarily on administrative actions to correct the majority of violations. Administrative actions generally are quicker, less expensive, and less resource-intensive than judicial actions. Federal agencies have administrative authority, but only half of the state environmental agencies are authorized to impose administrative penalties. The others must refer every noncompliance case to a state attorney general or district attorney for judicial action.

Informal Actions

Administrative enforcement often begins with an informal action, which can include any type of communication from an agency notifying a facility of a problem. A letter or telephone call can be appropriate where the violation is minor, such as with a record-maintenance problem. If the facility does not take corrective action within a set time period, a warning letter may follow, setting out specific actions to be taken and explaining the enforcement actions that will be taken if the facility does not comply.

Orders

For more severe violations or when a facility does not respond to an informal action, some regulatory agencies are authorized to issue administrative orders that may require compliance or corrective action.

- **Compliance orders.** Authorized agencies may issue an order requiring a facility to take steps to come into compliance. A compliance order may require immediate action or set a timetable to be followed in moving toward compliance. The order can contain a penalty for each day of noncompliance and can suspend or revoke a facility's permit. Loss of permit can force the closing of a facility.

  An order to stop illegal discharges or close down is the strongest administrative action possible. For example, the State of Virginia recently traced PCBs in local waters to a rayon fiber plant in Front Royal. When faced with the choice of stopping the illegal discharge or closing down, the plant closed its doors. Facilities can request a hearing to review an order. If no request for a hearing is made, most orders become final 30 days after issuance.

- **Corrective action orders.** Regulatory agencies with administrative authority can issue an order requiring corrective action at a facility when wastes have been released illegally into the environment. Such orders can suspend permits and impose penalties for each day of noncompliance.

Hearings

A facility receiving an administrative order from a federal agency can request a hearing to review the factual provisions of the order before an administrative law judge. Hired by the federal government's Office of Personnel Management, administrative

law judges serve in an independent capacity. After hearing a case, the judge submits recommendations to the agency director, who makes a determination. A facility can appeal a director's determination in federal court.

Arbitration

Environmental enforcers are using arbitration more and more frequently to settle certain types of cases. Alternative dispute resolution techniques offer a relatively quick and inexpensive option to traditional litigation and negotiation. For example, EPA has used arbitration to settle Superfund claims for recovery of response costs in toxic waste cleanups that do not exceed $500,000. In this voluntary procedure, EPA and one or more potentially responsible parties submitted the issues in a recovery claim for resolution to neutral third parties who act as arbitrators.[38] One of the strengths of arbitration is that arbitrators are usually well-trained or experienced in environmental science, in contrast to judges and juries who can be unfamiliar with the technical aspects of environmental cases.

Environmental Auditing

Environmental audits conducted by private auditors have become a popular enforcement mechanism. A new industry has grown up around these audits, which work something like private inspections. Since the mid-1980s, industries and federal facilities have been ordering audits to review industrial operations. Environmental audits, made by an independent unit within a facility or by outside professionals, can be of three types:

- **Compliance audits.** This type of audit reviews permits and management systems to evaluate status, but does not perform extensive sampling.

- **Transactional audits.** When a facility is changing hands, a transactional audit may be conducted to determine hidden liabilities.

- **Pollution prevention and waste reduction audits.** These environmental audits evaluate the technical structure of a plant and recommend operational changes that reduce waste.

Most audits are conducted on a voluntary basis, but the government can require a facility in violation of a law to have an environmental audit made as a provision for settlement. For example, in a 1989 consent-decree settlement with a Pennsylvania oil company guilty of a benzene discharge violation, a federal court imposed a $95,000 penalty and required an environmental audit.

Environmental audits help make environmental laws self-enforcing. EPA has 1,600 inspectors nationwide who conduct periodic inspections of public and private facilities. The 50 states have perhaps 16,000 inspectors. Private environmental auditors now number around 160,000. Although auditors can not take the place of government inspectors, they can help facilities identify internal sources of pollution and actions to control them.[39]

Sanctions

State and federal environmental laws provide for a range of sanctions against facilities in violation of environmental regulations. Because state laws can differ widely, similar offenses may be handled in very different ways in neighboring states. Administrative enforcement may include the following sanctions:

- **Contractor listing.** The Clean Air Act and Clean Water Act authorize regulatory agencies to bar the federal government from awarding contracts, grants, or loans to facilities with a pattern of noncompliance. In 1989 EPA listed 10 facilities and barred them from receiving government contracts; one facility was delisted when it returned to compliance. Under discre-

tionary listing, EPA officials, a state governor, or a member of the public can recommend listing. In 1989 one facility was listed in this way, six actions were initiated, and two were withdrawn when compliance agreements were reached. The public notoriety of being on the EPA List of Violating Facilities provides an added incentive for facilities to correct violations.

■ **Administrative penalties.** During the past decade, state and federal legislators have increased penalties allowable under environmental laws. Administrative penalties are generally smaller than civil penalties (see Table 5-13), which encourages violators to settle early in the process. In one EPA case, the agency attempted to settle with a violator for a $200 fine. No settlement was reached, and the case went to the Department of Justice for trial. A federal district court awarded the statutory penalty of $10,000. The incentive for violators to reach early settlements explains, in part, the small percentage of federal environmental violations referred to the Department of Justice.

Table 5-13.—Penalty Assessments in Civil Cases Referred to the Department of Justice by the Environmental Protection Agency and in Cases Handled Administratively by EPA, Fiscal Years 1974–89.

YEAR	CIVIL JUDICIAL	ADMINISTRATIVE	FY TOTAL
	..... $		
FY74	5,000	0	5,000
FY75	75,250	0	75,250
FY76	314,500	0	314,500
FY77	4,423,960	0	4,423,960
FY78	1,313,873	25,000	1,338,873
FY79	4,028,469	56,800	4,085,269
FY80	10,570,040	159,110	10,729,150
FY81	5,634,325	742,910	6,377,235
FY82	3,445,950	949,430	4,395,380
FY83	5,461,583	2,419,898	7,881,481
FY84	3,497,579	3,385,344	6,882,923
FY85	13,071,530	9,707,480	22,779,010
FY86	13,178,414	7,449,993	20,628,407
FY87	17,507,499	6,818,374	24,325,873
FY88	24,976,221	11,786,300	36,762,521
FY89	20,700,000	12,900,000	33,600,000
Total	128,204,193	56,400,639	184,604,832

Source: U.S. Environmental Protection Agency, Office of Enforcement and Compliance Monitoring, Washington, DC, Information Sheet (1990).

■ **Alternative payments.** In addition to a cash penalty, violators of environmental laws may be required to make innovative reparations. For example, a California corporation agreed to place an ad in *The Los Angeles Times* in February 1985, stressing the importance of complying with environmental regulations. The full-page ad read, "The illegal disposal of toxic wastes will result in jail. We should know. We got caught! Today, while you read this ad our President and Vice President are serving time in JAIL and we were forced to place this ad." In 1988 a Suffolk County Court in New York required the defendant in a felony hazardous waste case to place a full-page newspaper ad announcing the fine and jail term for reckless endangerment and warning of the consequences of polluting the environment. In other settlements across the country, violators have agreed to place ads, sponsor compliance training sessions at trade conventions, and fund grants for environmental research.

Judicial Actions

Violations of federal environmental statutes that require court action are referred to the Department of Justice. Violations of state and local laws are referred to appropriate legal agencies.

Civil Judicial Actions

For years, the number of civil referrals was the primary enforcement indicator for environmental agencies. With the increase in administrative and criminal sanctions, civil casework has become only one of several measures of performance. In 1989 the EPA had 900 active civil cases, and the average time needed to move from initiation to resolution was approximately two years, down by half since 1970.

■ **Consent Decrees.** Despite the number of referrals, relatively few environmental cases go to trial. Most end in a court-approved consent decree, in which a violator promises to correct a violation within a set timeframe and may pay a penalty for past violations. EPA currently is monitoring 600 consent decrees, involving facilities throughout the country.

■ **Civil Penalties.** State and federal courts have the authority to assess penalties for environmental violations. In the field of pollution control, EPA is charged with oversight of state civil penalty assessments. In the early 1980s, because penalties varied by state, violators in some areas did not take them seriously. In 1984 EPA adopted a Uniform Penalty Policy to help rectify the problem. In subsequent years, the dollar amount and the percentage of cases with civil penalties has increased.

Criminal Actions

The most publicized trend in criminal enforcement actions is the use of incarceration as a sanction. Debarment of government contractors charged with criminal violations of environmental laws is another, as is the cooperation of the public in reporting environmental crimes.

■ **Tougher Sentencing.** Incarceration for criminal violations is an enforcement trend that has been strenghtened by the sentencing guidelines of the U.S. Sentencing Commission. Since the guidelines took effect in 1987, more environmental crimes are now going to trial, rather than being resolved in negotiated plea agreements, as in the past. The reduced use of probation and community service has resulted in an increased number of jail terms.

■ **Contractor Suspension and Debarment.** In addition to contractor listing for civil violations, federal agencies may suspend or debar from participation in government-wide contracting those companies indicted

for a criminal violation of an environmental law. Contractors can gain unfair economic advantage over law-abiding competitors through intentional noncompliance with environmental regulations. Because a suspension can be initiated when criminal charges are filed, federal agencies can prevent violators from further endangering the public health or the environment while their cases go to trial.

■ **Citizen Rewards.** Federal and state enforcement agencies sponsor reward programs to motivate citizens to offer evidence in cases of environmental violations. For example, in 1984 the State of New York set up a reward program for information leading to the detection, arrest, and conviction of persons violating hazardous waste laws. EPA administers a Superfund Citizen Award Provision that pays up to $10,000 to anyone who provides information leading to a successful criminal prosecution. The Refuse Act, the Endangered Species Act, and the Shore Protection Act have bounty provisions, and many states administer Turn-in-a-Poacher reward programs. The Lacey Act authorizes the deposit of fines, assessments, and forfeitures in a Reward Account for those who provide information leading to a conviction.

The Fish and Wildlife Service initiated a reward action in 1985 involving an 11-year-old boy who assisted in the arrest of violators of the Endangered Species Act. The boy was night fishing with his father on a North Carolina beach, when he observed a 300-pound sea turtle coming ashore to lay her eggs. He was watching when three men approached and butchered the turtle, which is a protected species under the Endangered Species Act. Jotting down their license number, he called the local police, which led to the involvement of the state police, the state Department of Natural Resources, the Fish and Wildlife Service, and the U.S. Attorney's Office. The men were apprehended in a cooperative action by private, local, state, and federal enforcers, and the boy was awarded $2,000 for his college fund.

Private Enforcement Today

Responsibilities for environmental enforcement are divided between the public and private sectors. Private citizens have several legal options available to them for filing suit to force compliance with environmental laws.

NEPA Suits

Although the National Environmental Policy Act has no citizen-suit provision, it may have inspired more litigation than any other environmental law.[40] Since 1974 over 1,700 NEPA suits have been filed against federal regulatory agencies by citizens, businesses, local governments, and states. The suits claimed that a federal project either had no environmental impact statement or that the EIS was inadequate. Over 122 NEPA injunctions were obtained.

In the 1970s the suits focused on basics, such as the timing and scope of environmental impact statements. In the 1980s the suits began to challenge fine points of NEPA regulations, such as worst-case analysis and cumulative effects requirements, which were ultimately changed in response to the suits.

Toxic Torts

Law suits also are being filed to recover personal damages resulting from violations of environmental laws. Personal injury cases based on such violations are regulated by state and federal law. In a toxic tort, the plaintiff must establish actual harm and a causal link between the harm and the defendant's action. Thousands of tort lawsuits have been filed against the major asbestos manufacturers and against producers of other toxic materials.[41] Superfund cases in which responsible parties admit liability as part of a settlement have begun to spawn related toxic torts.

Citizen Suits

Beginning with the Clean Air Act amendments of 1970, private citizens are now authorized under seven environmental laws to sue environmental violators directly or to sue a regulatory agency for failure to perform its legal responsibilities. The Federal Insecticide, Fungicide, and Rodenticide Act is one of the few environmental laws that does not include a citizen-suit provision.

Although remedies are fewer in citizen suits than in toxic torts, evidentiary burdens are also less. In a citizen suit, the plaintiff can obtain an injunction against further actions of the defendant, penalties under the CWA, RCRA, and CERCLA to be paid by the defendant to the U.S. Treasury, and attorney's fees and costs. Proof of violation of a federal or state environmental standard is sufficient to win court relief. In a citizen suit, the plaintiff does not need to prove harm because of the violation, and no damages are awarded to the plaintiff, who is merely suing to stop the violation.

Prior to 1970, state laws such as the Michigan Environmental Policy Act authorized anyone, not just the government, to bring an action in a state court to prevent pollution, impairment, or destruction of the environment. Such statutes, often said to have created private attorneys general, were the precursor of the federal citizen suit.[42]

During the 1970s citizen suits were used primarily in test cases to compel the government to fulfill nondiscretionary duties. Only a few dozen suits were filed against individual polluters, while hundreds of nondiscretionary duty suits were filed against regulatory agencies. These suits reflected the strategy of the leading environmental litigants, among them the Natural Resources Defense Council, the Environmental Defense Fund, and the Sierra Club Legal Defense Fund. A suit seeking to require EPA to regulate toxic water pollutants could affect thousands of industrial dischargers, while a private enforcement suit against a polluter would apply to just one.

The Clean Water Act leads in numbers of citizen suits, many of which were inspired by a citizen-enforcement program led in the 1980s by the Natural Resources Defense Council and the Atlantic States Legal Foundation. The strategy was to compare discharge limits set out in a permit with the facility's own reported disposal levels, which are filed with EPA.

Before bringing a suit, citizens are required to give 60 days notice to the federal government, the state, and the violator. If the federal government or the state is prosecuting an enforcement action against the violator, citizens may not bring a separate action, but they may intervene in the litigation. A federal or state agency, when notified of intent to file a citizen suit, may initiate a separate enforcement action, join in the citizen's suit, or allow the suit to proceed and perhaps file an amicus brief on points of law.

In the past decade, most Clean Water Act citizen suits did not go to trial, but rather were settled when dischargers and environmental groups signed court-approved consent decrees. In many cases, the court also imposed a penalty. The largest citizen-suit penalty to date was assessed for $1.3 million.[43] Most penalties were paid to the U.S. Treasury, but in some cases payments have been made to environmental groups or to an environmental project unrelated to the suit.

Since 1979 more than 2,000 public notices have been filed announcing citizen suits. About two-thirds of the suits involved Clean Water Act violations, one-fourth were RCRA suits, and the remainder were Superfund cases. Many citizen suits cited more than one statute. The 1984 RCRA amendments allow a citizen to sue any past or present generator, transporter, owner, or operator of a treatment, storage, or disposal facility. Thus many of the RCRA citizen suits have been brought by owners of hazardous waste sites seeking to enjoin previous owners to share the liability.

By 1988 approximately 64 citizen suits had been settled out-of-court and 230 had gone to trial, including 200 Clean Water Act suits. Pennsylvania led the nation with 163 notices of intent to file citizen suits, 117 under the Clean Water Act. New York followed with 124 notices, of which 100 were Clean Water Act claims. Next came New Jersey with 76 notices and Connecticut with 72. The average time from notice to settlement varied from nine months in some states to four or five years in others. Citizen groups were not the only litigants. State agencies also filed citizen suits against municipalities and federal facilities in noncompliance with environmental regulations.

Citizen suits allow individuals to stop environmental violations not being addressed by public enforcers. While federal and state agencies take action against the most significant violations, citizen suits serve to supplement governmental efforts.

In some cases, public and private enforcers are beginning to join forces. For example, in 1989 the United States and STOP, Inc., a citizens group, sued the owners of an Indiana landfill for RCRA violations. The facility lacked an adequate groundwater monitoring system, and pollutants had migrated off site, contaminating private wells that provided drinking water for local residents. The suit resulted in a penalty of $2.8 million, the largest civil penalty assessed in a RCRA case. After a 6-week trial, a federal court ordered the owners to close their facility, conduct corrective actions, and pay the record-setting penalty.

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June 27, 1986

On June 27, 1986, the Massachusetts Department of Environmental Protection issued stringent new limitations on sources that discharged liquid wastes into the Ten Mile River. In response to those new standards, the Robbins Company, a medium-sized electroplating firm in Attleboro, Massachusetts, had to chose between two options, neither of which seemed very attractive. Tying into the local wastewater treatment facility would be expensive and uncertain, because regulations might change over the years. Upgrading its own treatment plant would cost approximately $500,000 in addition to high operating costs. In addition, on-site treatment would generate large amounts of metal hydroxide sludge. For the Robbins Company, on-site treatment would transform a water pollution problem into a solid waste disposal problem.

Instead, the Robbins Company chose to participate in a pilot program set up to help find alternative ways to meet the new standards. One option sounded particularly intriguing: a closed-loop system that would detoxify wastewater and send it back into the plant for further use. In fact, the Robbins Company went on to design and install what may have been the first closed-loop system of its kind in the nation.

Results have been striking. Since 1986 chemical use has dropped 82 percent; hazardous waste generation, 89 percent; water use, 47 percent; and the costs of laboratory analysis, 87 percent. These reductions translate into about $71,000 in direct savings in annual operational expenses. Moreover, installation and housing of the closed-loop system cost about $220,000—far less than the cost of upgrading the treatment plant. And the plating product has improved, because the recycled water is purer than the initial water source.

CHAPTER 6

Pollution Prevention

The term "pollution prevention" may well become the hallmark of environmental policy in the 1990s and beyond. In short, pollution prevention aims to reduce the amount and/or toxicity of pollutants being generated. It does this through any number of strategies: using less toxic inputs; redesigning products; altering manufacturing processes; conserving energy in homes, businesses, and power plants; and reducing the amount of agrichemicals used to raise crops and livestock.

As the concept evolves and case studies like the Robbins Company[1] multiply, several key characteristics of pollution prevention are emerging. They contrast sharply with the concept of pollution control that has dominated U.S. environmental policy for the past two decades, and they include:

- **Pollution prevention** means the reduction or elimination of pollutants at their source so that waste is not generated; it contrasts with "end-of-pipe," "collect-and-contain," or "release-and dilute" controls designed to treat or control releases and waste already generated.

- **Pollution prevention** emphasizes the efficient, and therefore more profitable, use of material and energy resources; it contrasts with the costly treatment of resource wastes that often are byproducts of inefficient use of materials or energy.
- **Pollution prevention** reduces the *total* amount of pollutants in the environment; it does not simply shift them from one environmental medium to another, as so many pollution control strategies do.

Pollution prevention also contrasts with pollution control in terms of its application and strategies. While end-of-pipe measures focus primarily on large, centralized facilities like power plants and sewage treatment facilities, pollution prevention can be applied at all levels of economic activity, including personal consumption patterns. And while pollution control relies on technological solutions, pollution prevention employs a range of strategies from information exchange to regulation.

Historical Perspective

The pollution problems confronting most Americans two decades ago were conspicuous and alarming. Lake Erie was suffocating from algal blooms fed by phosphate discharges; layers of smog covered many urban regions of the country; solid waste dumps were open and uncontrolled; wildlife populations were declining because of the widespread use of DDT.

Two Decades of Pollution Control

A sense of urgency helped propel the environmental activism that marked the 1960s and 1970s. Environmental legislation enacted during the 1970s emphasized pollution control equipment to treat the most immediate pollution problems: wastes from power plants, automobiles, municipal wastewater facilities, and manufacturing plants, for example. This approach was predicated, among other factors, on the "polluter pays" notion that assigned major responsibility for cleanup to the polluting entity.

In a recent report on environmental risk in the 1990s,[2] the EPA Science Advisory Board (SAB) characterized the end-of-pipe approaches of the 1970s as sensible, targeted, relatively efficient, and reasonably cost-effective, given the kinds of environmental problems that faced the nation then. Indeed, such control measures have resulted in measurable improvements in environmental quality. (Examples of such improvements are described in Chapters 1 and 8 of this report.) Control technologies and regulations will continue to be essential in an environmental protection strategy.

The SAB report also envisioned a shift from pollution control to pollution prevention. That vision was based on an increasing appreciation for the limitations of pollution control, which is largely remedial rather than preventive and media-specific rather than multimedia in scope.

First, control technologies generally do not eliminate a pollutant, but often serve to transfer it from one environmental medium to another. Air and water pollutants, for example, typically are concentrated through end-of-pipe controls into a form of sludge for disposal on land. Cross-media solutions are needed to avoid such transfers, which sometimes can be as environmentally threatening as the original problem.

Second, many of the environmental problems evident today are linked to numerous small sources of pollution rather than major "point" sources already regulated. Nonpoint sources, such as agrichemical runoff from farms, do not lend themselves easily

to conventional control approaches. Neither do indoor pollutants, such as radon, found in many homes and buildings across the country. For example, a recent estimate by the National Acid Precipitation Assessment Program puts total annual emissions of volatile organic compounds (VOCs) from all sources at 46 billion pounds. That is 17 times the amount reported by industrial sources in the 1987 Toxics Release Inventory. Over half the VOCs are emitted by mobile sources.[3] Such data strongly suggest the need for environmental protection strategies that extend beyond end-of-pipe pollution controls.

Tracking and analyzing an ever-expanding list of new pollutants—let alone controlling them—is a major challenge today. Approximately 63,000 chemical substances are in use commercially today, and new chemicals are being introduced in the United States at a rate of several thousand per year.[4] Conventional regulatory approaches simply cannot keep pace with such proliferation.

Moreover, pollution control techniques are subject to diminishing returns. That is, additional increments of environmental improvement are gained only at increasingly higher costs. Since the least expensive pollution control measures already have been mandated, future resources—in many cases—would be better invested in more productive forms of environmental protection—that is, pollution prevention.

Improved knowledge on the effects and interaction of pollutants point to possible new problems of unprecedented scale and uncertainty. Among the most publicized examples are acid rain, ozone depletion, and global change. More subtle examples include recent research documenting long-term and pervasive accumulation of toxic chemicals throughout the Great Lakes ecosystem.[5] Actions that serve to anticipate and prevent problems of such risk and potential irreversibility are only prudent.

Emergence of Pollution Prevention

The potential of pollution prevention in addressing the deficiencies of conventional controls has been recognized for a long time. For example, effluent guidelines under the Clean Water Act of 1972 include waste reduction as an option for "best available technology" controls. In 1975 the 3M Company initiated its pacesetting "Pollution Prevention Pays" program in response to a changing regulatory climate and in the belief that future competitiveness required a different attitude toward waste of any kind.[6] By the early 1980s several states had taken the lead in establishing technical assistance programs to help industries reduce their waste streams. Other states with aggressive prevention programs helped demonstrate the value of education and technical assistance for industries.

Several factors explain the recent surge of interest in pollution prevention. Economics is one of the most potent. By improving production efficiency and avoiding the costs of pollution treatment, control, and liability, companies can enhance their competitiveness. Treating pollution as a natural by-product of production is an outmoded concept in a competitive world where wastes can be designed out of production processes or even transformed into useful products or resources. Further, strong public demand for an improved environment reinforces the value of pollution prevention investments. Corporations that make such investments often gain public good will as well as lower waste disposal costs.

Pollution Prevention Today

The idea of pollution prevention is taking hold at all levels of American society. Recent pollution preventing activities have involved the public and private sectors as well as individual consumers.

Industry

Pollution prevention in the industrial sector is hardly a new concept. Industrial operations traditionally have adopted a variety of waste reduction techniques to lower costs of production and increase profits. But the nature of economic incentives and the corresponding emphasis placed on prevention as a management priority are changing rapidly.

Prior to enactment of the major environmental laws, little economic incentive existed for firms to engage in waste treatment. Actual costs of disposing wastes to the environment were very low, if not free. Moreover, the social costs associated with the resulting pollution were not assessed to the source. Waste reduction was pursued as long as it was profitable and information existed on available options.

Yet continued use of the environment as a given led to the pollution problems evident in the 1960s, and those problems in turn led to end-of-pipe controls. Investment costs for such control technologies were partially offset through depreciation tax credits, industrial revenue bonds, and grants to municipalities for wastewater treatment facilities.[7]

Pollution controls solve no problem. They only alter the problem, shifting it from one form to another, contrary to this immutable law of nature: the form of matter may be changed, but matter does not disappear . . . [I]t is apparent that conventional controls, at some point, create more pollution than they remove and consume resources out of proportion to the benefits derived . . . What emerges is an environmental paradox. It takes resources to remove pollution; pollution removal generates residue; it takes more resources to dispose of this residue and disposal of residue also produces pollution.[8]

— Dr. Joseph Ling
Vice President (Ret), 3M Company

In the past several years, economic incentives for firms to prevent the generation of wastes have strengthened significantly for several reasons. First, pollution control, cleanup, and liability costs are increasing. Second, costs of resource inputs—energy and raw materials—are increasing also, further encouraging their efficient use. Finally, public pressure on companies to decrease pollution has increased, magnified by new requirements under section 313 of the Superfund Amendments that require firms to report annual releases of toxic chemicals.[9]

These factors all have worked to elevate the priority of pollution prevention in the industrial sector, as evidenced by a burgeoning number of studies and publications devoted to the subject. The Congressional Office of Technology Assessment (OTA) has issued several reports on industrial hazardous waste reduction.[10] Two reports in 1985, one by INFORM, an independent nonprofit organization, and another by the National Re-

search Council, also focused on prevention strategies for hazardous wastes.[11] Since 1985 the League of Women Voters has sponsored annual conferences in Woods Hole, Massachusetts, to spread information on industrial waste reduction efforts. Trade journals are devoting more and more attention to articles on prevention strategies. Federal and state agencies are documenting an increasing number of pollution prevention success stories to share with industries. Although such successes are difficult to validate precisely, clearly American industry is emphasizing prevention strategies more than ever before.

Techniques to Prevent Pollution

Industrial pollution prevention strategies can be grouped into five general categories. Presented in order of decreasing importance to companies surveyed in the mid-1980s, the strategies are: in-process recycling, process modification, improved plant operations, input substitution, and changes in end products.[12]

In-Process Recycling

By the on-site recycling of waste products back into the production process, companies often can reduce pollution. For example, an IBM plant recycled two major waste solvent streams used to clean electronic and circuit boards. By recycling these two solvents, the amount of wastes requiring disposal was reduced by 95 percent. In 1984 cost savings were about $500,000. Between 1980 and 1985 over 1.5 million pounds of solvents were recycled.[13]

Process Modification

Many industrial firms have prevented pollution successfully by modifying production processes. Such modifications include adopting more advanced technology, improving the efficiency of equipment operation, optimizing raw material use, and modifying equipment to enhance material recovery.[14]

For example, Broyhill Furniture Industries improved production technology by replacing a conventional spray finishing operation with an electrostatic finishing system. With the new system, a sensitizing agent is applied to furniture to attract and hold finishing material, thus decreasing overspray and the amount of solvent needed for cleanup. Broyhill has saved $150,000 annually and achieved a 20-percent reduction in finishing and cleanup materials.[15]

Regulations sometimes play a constructive role in promoting waste reduction techniques that prove to be profitable. For example, Exxon installed "floating" roofs on storage tanks for acetone and other volatile chemicals at their facility in Linden, New Jersey, in anticipation of state regulations. Emissions reductions in 1983 were greater than 680,000 pounds per year—worth more than $200,000 in chemicals that would have been lost to evaporation. Yet the tanks cost only $5,000 to $13,000 each (in 1983 dollars).[16]

Improved Plant Operations

Industrial firms can implement a variety of improved management or "housekeeping" procedures that will aid pollution reduction. These include conducting environmental audits, establishing regular preventive maintenance, specifying proper material handling procedures, and implementing employee training and feedback programs.

The implementation of thorough environmental audits is an especially beneficial initial pollution prevention activity. Audits enable companies to inventory and trace input chemicals and to identify how much waste is generated through specific processes. Consequently, they can effectively target the areas where waste can be reduced and formulate additional strategies to achieve reductions. After conducting a waste audit, for example, the Chevron USA petroleum refinery in Richmond, California, found that 90 percent of its chromium and nickel discharges to the San Francisco Bay originated from just two small sources at their 2,900-acre refinery.[17] This knowledge enabled Chevron to substantially reduce its total releases of these substances through input substitutions and process modifications at the most problematic sites.

Input Substitution

Industrial firms can use less hazardous and/or more efficient inputs to decrease pollution. Input substitution has been especially successful in material coating processes, with many companies substituting water-based for solvent-based coatings. Water-based coatings decrease the amount of hazardous waste produced, decrease volatile organic compound (VOC) emissions, and conserve energy. Riker Laboratories, a pharmaceutical plant, switched to a water-based solvent in coating medicine tablets, leading to a 24-ton per year reduction in air pollution and saving the plant $180,000 in pollution control equipment that would have been needed to meet California's environmental regulations.[18]

Substitutes may take a more exotic form. For example, research currently is being conducted on an oil derived from the seed of a native African plant, *Vernonia galamensis*, a possible substitute for traditional solvents in alkyd resin paints. It is estimated that the United States uses 325 million gallons of alkyd resin paints annually. The use of vernonia oil could lead to a 20 million-gallon decrease in VOC emissions annually.[19]

Changes in End Products

Manufacturers also can reduce pollution by redesigning or reformulating end products to be less hazardous. For example, chemical products may be produced as pellets instead of powder, decreasing the amount of waste dust lost during packaging.[20] Unbleached paper products can replace bleached alternatives.

Redesigning products can be one of the most challenging avenues for preventing pollution in the industrial sector, because consumer acceptance of the new product may be uncertain. Moreover, product redesign may require substantial alterations in production technology and inputs. Thus refined market research and consumer education strategies, such as product labeling, may prove helpful.

Challenges and Opportunities

Several obstacles to pollution prevention suggest the enormous opportunities still available in the industrial sector. One problem is that many businesses, not only small ones, lack access to technical information on profitable pollution prevention strategies. As discussed later in this chapter, EPA, state agencies, and some local governments are committed to meeting this need through technical assistance and information clearinghouses.

Sharing information is not as simple and straightforward as it sounds. Large firms that operate in highly competitive markets often devote considerable research and development resources to devise strategies, such as pollution prevention, that improve their market position. Industries that do achieve technological breakthroughs usually are reluctant to share proprietary information with competitors. But many types of knowledge and technical information can be transferred without jeopardizing proprietary data—a fact behind EPA's new program to encourage information transfer from large companies to their smaller counterparts.[21]

A related challenge is the need for institutional changes that affect engineering design, basic research, and education. For example, many production engineers today are reluctant, or not equipped, to incorporate innovative pollution prevention ideas into an original design process, because they haven't been trained to do so. New curricula and accreditation standards, prompted and supported by industry, will be required to meet this challenge.[22]

Corporate leadership, a vital ingredient in successful prevention programs, is needed to overcome inherent resistance to change. For example, promotion of new accounting methods can be used to explicitly identify waste streams associated with specific processes and products rather than the common practice of identifying waste treatment costs as general overhead.[23] While some firms, such as Dow Chemical, adopted such methods nearly three decades ago, many others have yet to follow suit.

Managers at a Rhone Poulenc plant in the United Kingdom have found this type of accounting to be extremely effective at alerting them to waste problems. A computerized waste account-

ing system now keeps track of wastes and associated disposal costs. The developer of the system reports:

> *The first time I did this there was quite a sensation. I was besieged by calls saying, 'Are you sure? You must be joking,' and so on—it was an absolute revelation. They were jolted from blissful ignorance about their true production costs.*[24]

Finally, greater emphasis must be placed on changing product design, the pollution prevention strategy that ranked lowest in the mid-1980s survey. Pollution generated as a consequence of inappropriate design and/or use of consumer products may be more significant than the pollution directly resulting from manufacturing processes.[25] Pollution from product use is dispersed much more widely throughout society than pollution from manufacturing, and consumers often do not understand the risks associated with products they might use frequently. For example, many common household cleaning and garden maintenance products contain ingredients that are hazardous during use and upon disposal. More subtle examples include disposal of appliances or other consumer durables that could be redesigned for improved durability and fewer repairs. In all such cases, shifting emphasis to product redesign may be far more effective than attempting to influence individual behavior.

Efforts to build pollution prevention into product design are increasing. For example, an EPA-funded project directed by the Conservation Foundation is evaluating opportunities to reduce the volume and toxicity of municipal solid waste through product and packaging design changes, as well as changes in product use. Officials from 3M also see a promising future for pollution prevention, with special emphasis on product design:

> *Up until recently our program has been voluntary, but now we're giving it structure and goals. One goal that can be quantified is to eliminate 90 percent of our air emissions by the year 2000, and a second is to eliminate 50 percent of our solid waste by the same time.*
>
> *One [goal] that hasn't been quantified is to reduce the environmental impact of our products and their packaging, and another is to reduce pollution in the products and*

materials we buy from our suppliers . . . We're going to become more structured in our goals and in our process of identifying waste and carrying out company-wide programs to eliminate it.[26]

Improved data collection and assessment are critical to structure better goals, to track progress, and to further identify pollution prevention opportunities. The key to future prevention strategies may be what a top-ranking official from DuPont calls turning the problems of increased environmental constraints into opportunities:

For myself, I am convinced that the best response to the increasingly strong global pressures for environmental protection is to re-examine the ways we make our products, the materials we use, and the products themselves.[27]

Energy and Transportation

U.S. consumption of energy is linked to many of this country's most pressing environmental concerns. Emissions released to the atmosphere from fossil fuel combustion contribute to atmospheric degradation. Sulfur and nitrogen emissions contribute to acid rain. Nuclear fuel, while causing no acidic or CO_2 emissions, produces dangerous radioactive wastes. Each energy source presents its own set of tradeoffs between economic efficiency and environmental impact. Even hydroelectric power—which uses a renewable resource—can cause significant impacts on local and regional ecosystems.

As in the industrial sector, a certain amount of pollution prevention has been practiced in the energy and transportation sectors over the past decade at least, particularly through energy conservation. Some utility companies have promoted significant reductions in energy consumption through conservation measures. Automobiles now are much more fuel-efficient than before the oil crisis in the 1970s.

However, much more can be accomplished. Energy conservation and the development of alternative fuels are two pollution prevention strategies that can serve to "stretch" finite energy sources and reduce pollution while a transition is made to a wider use of cleaner, renewable energy sources.

At the heart of modern society lies an economy driven by energy use. Unfortunately, the same energy that brings us comfort, convenience and prosperity also brings us pollution, impoverishment and global warming. Our challenge is to maximize the benefits gained from energy consumption while minimizing the costs incurred.[28]

— Douglas Foy, *Executive Director*
Conservation Law Foundation
September 1989

Improvements in energy efficiency—getting the same amount or more energy services for less energy input—has tremendous potential for preventing pollution. On January 26, 1990, the U.S. Department of Energy (DOE) launched a series of energy efficiency and renewable energy initiatives. Deputy Secretary W. Henson Moore described the potential benefits for the environment:

> *Using energy more efficiently under these initiatives will also avoid damage to the environment by an estimated 800 million tons of carbon dioxide, 2.3 million tons of sulphur oxides, and 2.1 million tons of nitrogen oxides annually. The avoided carbon dioxide emissions result from these cost-effective steps that the government and the private sector can take now to reduce the threat of global climate change.*[29]

As is often the case with pollution prevention, cost-savings associated with these initiatives could be considerable. The DOE plan calls for an investment of $336 million over a 6-year period for a variety of programs. Potential cost savings in the next 10-20 years could exceed $32 billion for energy efficiency measures in just four areas: (1) replacing inefficient lighting in federal facilities with high-efficiency lighting technology; (2) relighting commercial buildings; (3) improving utility planning for efficiency; and (4) accelerating voluntary building guidelines and standards.

Given this magnitude of potential cost-savings, a natural question surfaces: If these investments are so profitable, why isn't it happening in the free market already? In launching a similar type of efficiency program in the New England area, the New England Energy Policy Council addressed that very question. Three obstacles were noted: lack of information on new technologies; lack of resources or incentives to make initial investments; and lack of sufficient action on the part of utilities, often due to lack of profit incentives to do so.[30]

Energy Conservation = Increased Competitiveness

As the figures on cost-savings would suggest, energy conservation can enhance economic growth and competitiveness. Between 1973 and 1985, for example, per capita Gross Domestic Product in the Organization for Economic Cooperation and Development (OECD) nations rose 32 percent, while per capita energy use decreased 5 percent.[31] Overall energy consumption in the United States per dollar of gross national product (in 1982 dollars) fell 26.1 percent from 1973 to 1988.[32] Between 1979 and 1986, the United States obtained seven times more energy from efficiency savings than from additional capacity.[33] And gains in efficiency occurred in all sectors—from households to industry.

A good case study is Japan, which has made significant gains in energy efficiency. The Japanese steel industry cut energy required per ton of steel produced by more than 75 percent between 1973 and 1986.[34] Overall Japanese energy use declined by 6 per-

cent between 1973 and 1985, while per capita Gross Domestic Product rose 46 percent.[35] Clearly, resources diverted from unnecessary consumption of energy become resources available for more productive investments.

Although the United States has made significant progress, it still ranks among the most energy intensive developed countries. Available data, though not fully comparable, suggest that this country uses about twice as much energy per unit of Gross Domestic Product as other western nations. Moreover, total U.S. energy consumption is at an all-time high.

While the need for continued progress is clear, the causes for this disparity need to be understood. First, the United States has a more dispersed population than other western nations. Second, the United States has extensive domestic energy resources that others lack.

Energy Efficiency

Improved energy efficiency may be realized by developing more efficient end-use technologies as well as more efficient production and delivery of energy. In the industrial sector, for example, electric motors can be made more efficient through speed controls. Sometimes simple changes can reap tremendous benefits, such as the substitution of fluorescent for incandescent lightbulbs. It is estimated that one high efficiency lightbulb, which lasts 10 times longer than low efficiency alternatives, can eliminate the combustion of 524 pounds of coal (or 220-382 pounds of carbon).[36]

In the residential sector, significant efficiency gains can be achieved in household appliances, which consume approximately 15 percent of this nation's energy. For example, even though refrigerators today are 30-70 percent more efficient than models in place 15 years ago, it is estimated that efficiency improvements can be increased by a further 75 percent based on available technology.[37]

Case Study: Electric Utilities

Electric utilities are a primary source of carbon dioxide emissions and of emissions of acid rain precursors. For example, nearly one-third of all U.S. CO_2 emissions are from electric utilities. Consequently, they can play a critical role in boosting pollution prevention by promoting energy efficiency among their industrial, commercial, and residential customers.

Traditionally, utilities have focused on increasing energy supply to meet the needs of consumers. In recent years, however, utilities have begun to implement a variety of demand-side management programs because of the high costs and procedural complexity involved in building new capacity. A 1987 survey found that more than 85 percent of U.S. utilities had initiated some kind of energy conservation program, with more than one-half started during the 1980s.[38] Such programs can include energy audit services to identify ways to reduce consumption; rebates to consumers who install energy saving devices; loan programs to help consumers finance investments in energy saving equipment; and provision of free energy efficient equipment.

An ambitious demand-side management program has been launched in New England. The impetus for such a program is not hard to understand. In 1987 New England states spent more than $7 billion annually for electricity, at rates that were 25 percent above the national average. Average electrical use in the region had been growing more than 5 percent a year since 1986, despite industry forecasts of about 2 percent. Power brownouts in 1987, the first in more than a decade, underscored constraints in existing energy supplies.[39]

In 1987 the Conservation Law Foundation assembled a team of energy experts and utility managers from around the nation to examine the economic and technical feasibility of using energy conservation to help address New England's power needs. Their subsequent report, *Power to Spare*, gained immediate response from most of the major electric utilities in New England. The report stressed three advantages of energy efficiency: (1) it is less costly than new power plants; (2) it is less risky than power plants with their long lead times and unpredictable construction; and (3) it is environmentally clean.

Working cooperatively with the Conservation Law Foundation, the New England Electric System, which supplies power in Massachusetts, Rhode Island, and New Hampshire, announced a $65 million energy conservation program in September 1989. Projects include $12 million for efficient lighting and cooling systems for existing large commercial and industrial structures, as well as assistance for developers of new homes. Energy savings in 1990 are projected to reach 168 megawatts of electricity—more than that offered by a small power plant.[40]

DOE has sponsored a nationwide demand-side management program, called "Least-Cost Utility Planning" (LCUP). This program has funded projects in all parts of the country to demonstrate both efficient technology and electricity demand reductions. Environmental benefits and ways to include environmental externalities in regulatory rate-setting activities at the state and federal level are being included in LCUP. Based on this program, DOE has estimated that a nationwide reduction in electricity demand of approximately 30 gigawatts (billion watts) could occur by 2010.[41]

Alternative Fuels

Cars, trucks, and buses have long been major sources of air pollution in the United States. In response to their contribution to air quality problems, especially in urban areas, Congress included various provisions dealing with mobile sources in the Clean Air Act in 1970. That law set up the Federal Motor Vehicle Control Program, which authorized EPA to set emissions standards for carbon monoxide, nitrogen oxides, volatile organic compounds (VOCs), and particulates, among others. EPA also used its authority under the Clean Air Act to phase out the use of lead in gasoline.

Although end-of-pipe controls, such as catalysts, undoubtedly have gone a long way to protect air quality in this country, the technical difficulty and cost of further improving them suggests that further long-term reductions in mobile source emissions may require the use of alternative fuels as well as improved control technologies. These fuels include ethanol, liquid propane gas, hydrogen, electricity, compressed natural gas (CNG), reformulated gasoline, and methanol. The last two—CNG and methanol—are being actively pursued in various states and urban areas in the United States.

Compressed Natural Gas (CNG)

CNG vehicles, which store natural gas in tanks at high pressure, are the most common type of alternative-fuel vehicles on the road today. Half a million CNG vehicles are in operation worldwide: 300,000 in Italy; 120,000 in New Zealand; 30,000 in the United States; and 17,000 in Canada.[42] Most CNG is used in buses, delivery vehicles, and government fleets. Natural gas companies own half of such vehicles in use in the United States today.

CNG, like all alternative fuels, has various advantages and disadvantages. While existing CNG-fueled vehicles are relatively more expensive than gasoline or methanol vehicles, this cost could be offset by lower fuel and maintenance costs. CNG-fueled vehicles also are relatively safer than gasoline vehicles in cases of tank rupture.[43] On the other hand, current CNG vehicles have a limited driving range—about 200 miles—and some must be

refueled overnight. In addition, the current generation of vehicles is "dual-fueled," meaning that they also contain a gasoline tank and can switch back and forth between the two fuels. Although this feature makes them more convenient to drive, the emissions reductions are not as great as with a vehicle "dedicated" solely to CNG. For example, VOC emissions from a dual-fueled system are estimated to be about 15 percent higher than those of a dedicated system.[44]

Methanol

Far fewer vehicles currently use methanol, a liquid fuel generally made from natural gas. Approximately 1,000 methanol vehicles are in use in the United States and fewer still in the rest of the world, although the number is growing rapidly.[45] The California Energy Commission (CEC) has been the driving force in the development of methanol vehicles, most notably with its purchase of 506 methanol-powered Ford Escorts in 1983. Most of those cars are still on the road, and the fleet has accumulated nearly 20 million miles.

Virtually all of the methanol vehicles now operating run on a mixture of 85 percent methanol and 15 percent gasoline, known as M85. They are often "flexibly fueled," meaning that they can run on M85, gasoline, or any combination of the two. Because methanol-fueled vehicles are expected to be relatively inexpensive when mass produced, offer higher performance, and use a liquid fuel, potential consumer acceptance is judged to be much greater than CNG for use in passenger cars.

However, methanol presents several drawbacks. Supplies necessary to fuel large numbers of vehicles are not available without construction of new plants. Modifications would have to be made to materials in vehicles and filling stations, since methanol destroys some plastics, metals, and lubricants. Methanol is also highly toxic if ingested.

Potential for Reducing Emissions

Based on the most recent estimates made by EPA,[46] the next generation of methanol and CNG-fueled vehicles has substantial potential for reducing air pollutants. Rather than being flexible-fueled, those vehicles would be designed for the dedicated use of CNG or pure methanol, called M100. Comparing dedicated-use vehicles with automobiles that meet California's current emissions limits, the most stringent in the nation, EPA estimates the following effects on emissions:

- Total hydrocarbons that react in the atmosphere to form ozone could be reduced by 80 percent for M100 vehicles and 80-93 percent for CNG vehicles.

- Total reduction in various carcinogenic air toxics also could be reduced substantially. For example, benzene could be reduced by 80 percent for M100 vehicles and by 98 percent for CNG vehicles. Other toxics, such as particulate organics, could be reduced more than 99 percent using either type of fuel. While M100 could increase formaldehyde emissions at the tailpipe by 200 percent, formaldehyde as formed in the atmosphere could be cut by 80 percent by either fuel. In total, EPA estimates that methanol and CNG could reduce the cancer incidence linked to such air toxics by more than 85 percent.

Emissions tradeoffs between M100 and CNG vehicles are compounded by other challenges peculiar to the fuels or vehicles. For example, researchers are investigating M100's need for a cold-weather starter and additives to give it odor, color, and luminosity. Only a small number of M100 prototypes have been built, and they are at a very early stage of development.

Challenges and Opportunities

The challenges in energy and transportation include the pursuit of new technological advances that will offer consumers more choices to help conserve resources.

Energy Conservation

Opportunities to advance pollution prevention through energy conservation are still plentiful. The rate and degree to which those opportunities are grasped hinges largely on whether or not adequate incentives exist.

For example, opportunities for utilities to conserve energy will expand if there are incentives to invest in demand-side management programs. Some utilities now are being allowed to make profits from energy conservation investments as they do now from investments in additional capacity. California has adopted innovative regulations that sever the link between utility energy sales and revenues as a means to encourage such demand-side management strategies.[47] Wisconsin, Maine, and New York also have developed incentive mechanisms to overcome barriers to conservation programs. At least 10 states have required utilities to implement programs for "least-cost planning," in which utilities determine whether energy efficiency measures can supply consumers with services equivalent to those provided by new generating capacity and at lower cost.[48]

Alternative Fuels

Clearly, pollution prevention efforts through the use of alternative fuels hold enormous potential for the future. Their use can reduce pollutants, such as volatile organic compounds, but in some cases, they can increase other pollutants. Tradeoffs in terms of emissions reductions, system costs, and feasibility for widespread use are complex and not fully understood.

Experience in other countries using CNG vehicles has shown that government support, in the form of research and development as well as economic incentives, has helped to spur adoption of alternative-fuel vehicles. In this country, Congress passed the Alternative Motor Fuels Act (AMFA) in 1988 to encourage the adoption of alternative fuels. The Act allows auto companies building alternative-fuel vehicles to take a credit on their Corporate Average Fuel Efficiency (CAFE) standards. It also authorizes DOE to spend $18 million over four years to fund alternative fuels demonstration programs.[49] In addition, EPA and DOE, working through the Alternative Fuels Commission estab-

lished by AMFA, will evaluate the health, ecological, and welfare benefits associated with switching to alternative fuels.[50]

Agriculture

Since the 1940s the agricultural industry has tended to substitute relatively less expensive inputs for labor and machinery. These inputs include energy, chemical fertilizers and pesticides, irrigation, antibiotics and hormones, and sophisticated products from plant genetics and technology. Productivity has increased significantly, allowing fewer farmers to produce more output than ever before, but it has become clear that many of these intensive practices produce serious environmental side effects:

- Nearly two-thirds of the surface water quality problems caused by sediment runoff is attributed to agriculture.[51] Damages from cropland soil erosion alone have been estimated at $3.2 billion a year.[52]
- Groundwater supplies are increasingly affected by agricultural chemicals. Recent monitoring samples detected 46 pesticides attributed to agricultural use in the groundwater of 26 states.[53]

Pollution Control

Traditional environmental policy in agriculture has relied almost exclusively on voluntary practices and programs to reduce soil erosion, including the use of cost-sharing incentives for soil conservation. Several inherent characteristics of the agricultural sector contribute to the voluntary approach: (1) the large number of farms, about 2.1 million; (2) the diversity of farm operations, such as various crops and livestock, compounded further by varying conditions of climate, soil, water resources, and topography;

(3) the "nonpoint" nature of erosion and agrichemical runoff, which makes it difficult to identify exact sources of pollution and to remedy pollution problems; and (4) the perception that farmers lack adequate economic incentives to undertake conservation practices that may yield benefits only in the long term, such as improved soil productivity, or to other parties, such as downstream users.

Some soil conservation measures both prevent pollution and control it. For example, field terraces control erosion by retaining sediment already displaced above the terrace. At the same time, terraces also help prevent erosion by retarding the rate at which rainfall flows over a field. Grassy strips lining a streambank, in contrast, do not prevent erosion, but they do help prevent the pollution of water from sediment and agrichemicals. Measures such as conservation tillage help prevent erosion, but they can present tradeoffs in the form of increased use of pesticides to control weeds and insects.

This traditional emphasis on voluntary action shifted to some extent with passage of the 1985 Food Security Act. Title XII, in particular, incorporated an unprecedented system of incentives and penalties to help address growing concern over agriculture's impact on the environment at large. Water pollution and degradation of fish and wildlife habitat are just two examples of these "off-site" impacts.

Several of the Title XII programs help to prevent pollution, because they constrain activities that would result in erosion and related pollution problems. However, they do so by taking existing or potential cropland out of production altogether. For example, the Conservation Reserve Program has converted nearly 34 million acres of cropland to long-term vegetative cover for 10-year contract periods in exchange for annual payments and cost-sharing assistance to establish cover and other practices. Sodbuster provisions prohibit cropping on designated lands without approved conservation plans under penalty of forfeiting federal commodity program payments. Swampbuster provisions prohibit conversion of designated wetlands to produce crops. Thus, these three programs do not focus on preventing wastes through more efficient agricultural practices.

Emergence of Pollution Prevention

Recent developments, however, are encouraging a pollution prevention approach in agriculture—primarily through the reduction of agricultural inputs. The developments include (1) growing public concern for the amount of chemicals in food supplies and in the environment in general; (2) an accumulation of research findings and case studies pointing to the benefits of low-input agricultural methods; (3) increasing costs of pesticides as well as restrictions on specific pesticides as a result of the EPA accelerated pesticide registration process; (4) increasing resistance of insects to pesticides; and (5) an expanding number of federal and state programs aimed at researching and demonstrating the effects of low-input agriculture. While some farmers have always used pollution prevention practices, the incentives described above are encouraging expanded applications.

Referred to variously as "alternative" or "sustainable" agriculture, low-input sustainable agriculture (LISA) has potential for reducing environmental damages associated with intensive agricultural practices. The LISA goals are consistent with the concept of pollution prevention: to conserve resources, reduce environmental damages, and promote food safety while being productive and profitable for the farmer. To accomplish these goals, LISA uses a combination of methods tailored to the needs of each crop and farm. Low-input agricultural practices include crop diversification, integrated pest management, crop rotations, use of animal manure and leguminous crops, mechanical cultivation, cover crops, strip cropping, alternative animal disease prevention strategies, and a variety of other measures.

The Administration's 1991 budget proposals include a $28 million increase devoted to the U.S. Department of Agriculture's efforts to better understand the causal linkage between production practices and water quality degradation. Protection of the nation's water resources from contamination by agricultural chemicals and nutrients is a key priority of the Administration. The 1991 budget funds the second year of a Water Quality Initiative proposed by the President to promote the development and adoption of environmentally sensitive farm production practices and safer chemical and biological pest controls. In total, the budget provides over $300 million for this purpose.

Ultimately, farmers must be responsible for changing production practices to avoid contaminating ground and surface waters. Federal and state governments can provide valuable information and technical assistance to producers, however, so that such environmentally sensitive techniques can be implemented at minimum cost. The proposed increase in the FY 1991 budget will allow the Soil Conservation and Extension Services to expand their efforts to transfer to farmers scientific information about the vulnerability of natural resources to chemical pollution. Demonstration projects targeted to particularly environmentally sensitive geographic regions will receive the highest priority.[54]

Potential of Low-Input Agriculture

Much of the discussion of LISA's merits can be attributed to a 1989 National Academy of Sciences report entitled *Alternative Agriculture*. While findings were based on selected case studies rather than systematic research, the authors were nonetheless enthusiastic about the potential of LISA, reporting that: "Farmers successfully adopting these systems generally derive significant sustained economic and environmental benefits. Wider adoption of proven alternative systems would result in even greater economic benefits to farmers and environmental gains for the nation."[55] One NAS case study is highlighted below to illustrate the use of alternative practices.

An Iowa farming couple grow corn, soybeans, oats, and hay on their 300-acre farm, in addition to raising livestock. The family has experimented with a variety of LISA methods over the years. For example, because ridge tillage and mechanical cultivation are used to control weeds, herbicides are rarely used. Some techniques have multiple benefits. Cover crops control weeds and protect the soil; soil erosion on the farm is 1-4 tons/acre/year (tpa), compared to a county average of 8-10 tpa. Crop rotations also control insects and improve yields. For example, the farm yields 130-150 bushels/acre of corn (versus the county average of 124) for $75/acre less than the conventional farm. Using an assortment of methods, the family is able to raise healthy cattle and hogs with little use of antibiotics.[56]

Field Monitoring in Low-Input Agriculture

Careful monitoring of field conditions is a tool in the cost-effective reduction of overall applications of fertilizers, pesticides, and irrigation water. For example, soil tests can be used to determine which fields need fertilizers and at what levels. "Scouting" for threshold levels of pests is the monitoring device used in integrated pest management (IPM). Rather than spraying as a preventative measure or upon first observation of a pest, chemicals are used only when the potential damage of a pest exceeds the cost of applying the pesticide.

Benefits from irrigation efficiency extend far beyond conserving scarce water supplies—a major advantage in itself for many regions. Irrigation runoff can contaminate wetlands and waterways with damaging concentrations of salt, pesticides, and various toxic elements, such as cadmium and selenium that occur naturally in desert soils. Such pollution problems have increased significantly in tandem with the doubling of farmland under irrigation since 1945.

A 3-year demonstration project sponsored by INFORM tested the potential of one method to conserve irrigation water in California. Small electronic devices, called gypsum blocks, were used to monitor increases in soil moisture caused by irrigations and decreases caused by crop water consumption. Project participants found the costs for gypsum blocks and labor amounted to about $2 per acre. Resulting benefits from lower water and energy costs and improved yields were found to amount to $50 or more per acre. As noted by the researchers:

> *Sometimes the gains from using the method can be spectacular: An INFORM test on one strip of a 160-acre alfalfa field indicated that by using about 30 percent less water on the entire field the farmer could have earned $20,000 or more in higher hay yields alone.*[57]

Federal and State Programs to Promote Low-Input Agriculture

Various federal and state programs testify to the surge of interest in low-input sustainable agriculture. The 1985 Farm Bill authorized for the first time a grant program specifically for LISA-related research and education. Congressional appropriations thus far amount to $3.9 million in FY 1988 and about $4.4 million per year in FY 1989 and FY 1990 to fund projects.

One project, costing about $200,000 in federal and matching funds, investigates the possibility of substituting legume crops in place of fallow cropland in Great Plains wheat production. Growing legumes with grains in humid areas has been shown to reduce soil erosion, fix atmospheric nitrogen, reduce pesticide and fertilizer inputs, reduce weed competition, and increase net return per acre. However, traditional legumes have not been popular in semi-arid conditions, because they compete for water needed by the next wheat crop. The project is investigating alternative species that need less water.[58]

Integrated Pest Management (IPM) programs in the U.S. Department of Agriculture have a much longer history than LISA. The Extension Service received its first $500,000 IPM appropriation in 1972, largely in response to the environmental concerns raised in Rachel Carson's landmark book, *The Silent Spring*. Funding gradually increased to a peak of $7.5 million in FY 1981, and it has since continued at about 7.1 million per year. The success of IPM in the 1980s is attributed largely to the proven economic benefits accruing to many farmers.[59]

In 1987 the Appropriate Technology Transfer for Rural Areas (ATTRA) program initiated a toll-free service (800-346-9140) to provide information on low-input sustainable agriculture. The service is receiving increasing numbers of inquiries, with a total of about 9,000 calls received to date.[60]

States also are undertaking initiatives to explore and demonstrate the potential for low-input agriculture. A prime example is found in Iowa, where legislation enacted in 1989 authorizes at least five model farm demonstration projects across the state.[61] While all projects are intended to implement in-

tegrated, efficient farm management, each will be tailored to address special problems or characteristics of its region. For example, a project in southeast Iowa will focus on conservation tillage; another in the south-central part of the state will focus on forage management. In total, nearly 200 farms will participate in the demonstration program, and an aggressive information program is intended to reach nearly 140,000 farms.

Challenges and Opportunities

Despite the recent changes made in agricultural policy, government programs still appear to create barriers to the adoption of alternative agricultural methods. In particular, federal commodity support programs are based on the amount of acreage devoted to particular crops, such as corn, soybeans, and cotton. This tends to discourage crop rotations or the planting of a mix of crops that would help reduce soil erosion and the use of agrichemical inputs. Various proposals being discussed for future farm legislation could help remove this disincentive by linking receipt of commodity support payments to total program crop acreage instead of to production of particular crops.

Low-input sustainable agricultural practices are not a panacea. They tend to substitute time and management skills for intensive inputs such as agrichemicals. This goes against the trend of substituting relatively cheaper chemically intensive practices for expensive labor evident over the past several decades. Price changes that reflect the full social costs of chemically intensive inputs, together with technical assistance and information on the benefits of alternative practices, may be needed to help reverse this trend.

Low-input practices also may not be as profitable as conventional agriculture practices, especially given government support programs, and transition may be costly. Environmental effects from low-input practices are not fully understood and can be affected by certain tradeoffs: conservation tillage can increase the need for chemicals to help reduce weed and insect problems; use of manure can contaminate ground and surface water with nitrates just as chemical fertilizers can; and IPM scouting prac-

tices can lead to use of substitute pesticides with uncertain or different environmental consequences. Clearly, an urgent need exists for more research on these types of tradeoffs and on the economic and environmental implications for widespread adoption of alternative practices in U.S. agriculture.

Households: The Consumer

One of the important features of pollution prevention is that it works in all sectors of the economy and at each level of society. Actions by consumers ultimately determine the extent to which pollution prevention is incorporated throughout society. Consumer demand largely determines the types and quantities of products made; consumer choices and lifestyle decisions also affect land use patterns, how much energy is consumed, and what wastes are disposed of in the environment. Public attitudes also shape the political decisions that culminate in government policy.

The effects of individual actions on the environment are well-documented. For example:

- **Solid waste.** Per capita generation of municipal solid waste has increased by 36 percent from 1970 to 1986—from 3.22 pounds per day to 3.58.[62] Although strictly comparable data are not available, estimates place the U.S. per capita rate about one pound per day higher than that of West Germany.

- **Vehicles.** The per capita number of miles driven in vehicles each year has increased sharply since 1970. While the total U.S. population grew by about 22 percent from 1970 to 1989, the number of vehicles increased by about 56 percent and the number of vehicle miles traveled increased by about 48 percent.

Pollution Prevention at Home

At least two major routes to pollution prevention are possible in the household sector: (1) changes in the toxicity of materials or in the efficiency of the goods and services purchased; and (2) changes in consumption or usage patterns of those goods and services. With respect to energy conservation, for example, individuals can choose to purchase high-efficiency products or use energy-consuming goods less frequently. Individuals can purchase fuel-efficient vehicles or switch to alternative fuels if available; they also can use mass transit or take other actions to reduce the number of miles driven. In many instances, of course, individuals can exercise some combination of these options.

Individual consumers also can help determine how profitable pollution prevention alternatives will be to producers. In short, pollution prevention in the household sector pivots largely on the extent to which the marketplace encourages products and services that help improve the environment. In this sense, "marketplace" is not restricted to manufactured goods, but covers other types of economic activity such as land use development patterns.

Use and disposal of materials presents pollution prevention opportunities at home. Household managers can reduce the toxicity of substances introduced to landfills or wastewater by substituting less hazardous products or properly disposing of hazardous products, such as pesticides, solvents, motor oil, and paints. Materials sent to landfills or incinerators can be reduced through better production selection and active recycling of paper, glass, aluminum, plastics, oil, and yard wastes.

Consumer Attitudes and the Marketplace

Public concern and support for environmental quality have never been stronger, according to recent polls and surveys. One of the most widely cited polls, for example, finds that 80 percent of the people polled agreed that "protecting the environment is so important that requirements and standards cannot be too high, and continuing environmental improvements must be made regard-

less of cost."[63] Likewise, a recent Gallup survey found that about 39 percent of Americans strongly identify themselves as environmentalists.[64]

The most direct indicator of consumer behavior, however, is to observe choices actually made in the marketplace. The recent reaction against the use of Alar, for example, clearly demonstrates the market force that can be wielded when food safety is questioned. Public concern over pesticide residues is creating such a broad market for pesticide-free produce that demand has outstripped supplies. And although only one percent of U.S. produce is organically grown today, experts predict a rapid increase to perhaps as much as 10 percent by the year 2000.[65] Significantly, consumers are demanding such products despite their higher prices in current markets.

Producers today view public demands for a cleaner environment as strong stimuli for the pollution prevention strategies they are undertaking. For example, Procter and Gamble recently began test-marketing a product—a concentrated fabric softener—with the following environmental claim: "Better for the Environment . . . Less Packaging to Throw Away." The concentrate when mixed with water, makes about three times as much softener. The package is 75 percent smaller and costs about 10 percent less than the regular product.[66]

Public Sector Responses and Initiatives

Federal, state, and local governments are sponsoring pollution prevention programs, and initiatives at each level offer distinct advantages.

Federal Agencies

Creation of an EPA Pollution Prevention Office in 1988 signaled the agency's formal commitment to supplement vigorous enforcement of environmental laws with a broad-based pollution preven-

tion strategy. The agenda of the Pollution Prevention Office includes the following objectives: (1) ensuring that pollution prevention concepts are incorporated into every feasible aspect of internal EPA decisionmaking and planning; (2) providing financial and technical support for state and local pollution prevention programs; (3) developing an outreach program to emphasize the opportunities for and benefits of pollution prevention; (4) developing and maintaining a multimedia clearinghouse; and (5) collecting, analyzing, and disseminating data to target opportunities and evaluate national progress in pollution prevention.

Examples of EPA accomplishments to date include:

- **A 2 percent set-aside of EPA FY 1991 contract dollars for an agency-wide competition for innovative project proposals.** Such projects include, for example, a proposal to train permit writers to identify and incorporate multimedia source reduction and recycling requirements into media-specific permits. Another project will use enforcement agreements to commit violators to undertake appropriate source reduction or recycling. Still another will help establish university-based centers that will act essentially as limited extension services for pollution prevention.

- **A total of $7 million in state grants in 1990 for multimedia pollution prevention projects.** For example, Michigan's "Source Reduction Intern Program" will receive $240,000 from EPA to train state environmental personnel, graduate students, and others to perform waste audits and provide technical assistance to businesses. Primary targets will be small and medium-sized electroplaters and automobile assembly and component parts plants.[67] EPA plans to award an additional $6 million in state grants in 1991.

- **Sponsorship of a series of waste minimization workshops across the country.** The workshops, which use case studies to teach methods for identifying pollution prevention opportunities, are targeted to specific industries such as chemical manufacturing, wood preserving, textiles finishing, and carpet manufacturing.[68] Such

Case Study: Pollution Prevention in the Department of Defense

The Department of Defense (DOD) generates an estimated 200,000 to 500,000 tons of hazardous wastes a year including solvents, acids, contaminated sludges, and heavy metals.[69] Since February 1987 DOD has been implementing a hazardous waste minimization policy. In response, each of the major waste generating commands within DOD has established 50-percent reduction goals in hazardous waste generation by 1992.

Although some of the department's waste is produced in the manufacture of explosives, about 80 percent results from maintenance, including cleaning, painting, and repair work.[70] The potential for hazardous waste reductions is significant. At the Naval Torpedo Station in Keyport, Washington, paint finishes on torpedoes formerly were stripped off with chemicals. Switching to a method that blasts the paint off with plastic pellets eliminated use of hazardous solvents and 3,500 gallons of hazardous wastewater each week. In addition to saving more than $200,000 annually, workers are not exposed to hazardous chemicals, and energy is saved due to lower ventilation requirements.[71] Similar use of plastic media blasting to strip paint from aircraft at Hill Air Force Base in Utah is estimated to save $2.8 million annually in waste disposal, energy, manpower, and materials.[72]

efforts reflect the EPA philosophy that the most constructive way for government to promote pollution prevention is to provide waste generators with information and assistance.

■ **Creation of an information clearinghouse.** It consists of four components—a reference library, a hotline (1-800-424-9346), an electronic bulletin board, and outreach activities. The Electronic Information Exchange System (EIES) is accessible to anyone with a PC and a modem. It contains case studies, a calendar of training events and seminars, a directory of experts, a bibliography of abstracts and publications, and descriptions of state and federal activities. EPA has donated an EIES system to the United Nations Environment Program to establish an international network of EIES users.

■ **Establishment of a program through the Office of Research and Development to help transfer waste reduction lessons learned in various federal agencies to the private sector.** A series of assessments and demonstrations are being conducted cooperatively with the Departments of Defense and Energy, the Department of Veterans Affairs, the Coast Guard, and other federal agencies.

Interstate and Regional Programs

Two interstate efforts illustrate the recent surge in pollution prevention across the country. The National Roundtable of State Waste Reduction Programs was organized in 1985 to share information on state experiences and innovations. Since then, membership has grown from 7 states and 20 participants, to nearly 40 state members and 200 participants including representatives from EPA, Congress, and national environmental groups. The Roundtable now serves as a channel of communication between federal and state officials and as a key player in the evolution of pollution prevention policy at the federal level.

In 1988 the Coalition of Northeast Governors (CONEG) undertook an ambitious program to reduce municipal waste problems in its nine states.[73] Drawing on the technical expertise of a broad-based steering committee, CONEG Governors announced on January 5, 1990, legislative proposals to ban the use of lead, cadmium, mercury, and hexavalent chromium in product packaging that is manufactured and distributed in the region.

State Programs

At least 35 states have developed waste reduction programs since New York's original effort in 1981. The state programs share several common characteristics and trends, despite their diversity in organization, funding, and operations.[74]

Many programs, for example, grew out of controversies over the siting of hazardous waste facilities. Public concern over the

amounts of hazardous wastes being generated, and problems in locating suitable disposal sites, were stimuli for programs to help reduce and recycle wastes. While many programs retain an emphasis on hazardous wastes, as well as recycling, they are broadening gradually to include more multimedia activities.

States are beginning to secure formal legislative mandates for their prevention programs. Newer programs also are more likely to be located within a regulatory agency, rather than within universities, nonprofit organizations, other state agencies such as those dealing with commerce, or nonregulatory environmental organizations. Some states, such as Massachusetts and North Carolina, have programs in different agencies.

However, the most effective structuring of pollution prevention programs with state government remains an issue of debate. For example, industries may be more reluctant to open their records to staff from a regulatory agency than to staff without enforcement responsibilities.

Most state programs emphasize information and technical assistance services for small and medium-sized firms. Four states—California, Massachusetts, North Carolina, and Oregon—recently have required industries to submit documentation relating to pollution prevention.

The types of innovative pollution prevention programs that states are undertaking range from cooperative, nonregulatory programs to legislative measures requiring industries to develop and carry out plans for reducing use of toxic substances.

Minnesota's Technical Assistance Program (MnTAP)

Located at the University of Minnesota, MnTAP offers an acclaimed student intern program to provide assistance to small and medium-sized companies.[75] Participating companies select a highly qualified engineering or chemistry student for a summer internship. Under the supervision of assigned program and industry personnel, students conduct a technical audit and analysis of options tailored to a specific waste reduction problem. Three of the past four projects in 1989, for example, focused on substitutes for solvents that produce chlorofluorocarbon (CFC) emissions.

The MnTAP program exemplifies pollution prevention ventures that benefit all participants. The business is helped to reduce harmful wastes, the student obtains hands-on experience, and MnTAP itself gains valuable technical information to share with other companies.

In a different kind of internship program, Tennessee and Florida have employed retired engineers to assist companies with waste reduction efforts.

North Carolina's Pollution Prevention Program

Established in 1983 as one of the first multimedia waste reduction programs, the program organizes and sponsors the National Roundtable of State Reduction Programs and hosts the Southeast Waste Reduction Resource Center. The program functions as the state's lead agency for waste reduction, coordinating with other boards, agencies, and universities. Beyond the various workshops and outreach efforts, the program offers on-site technical assistance, an information clearinghouse with more than 3,000 publications, a research and education program, and demonstration grants. In addition, it facilitates a Governor's Award for Excellence in Waste Reduction.

Recent legislation considerably bolsters the state's capabilities for monitoring waste reduction opportunities and activity. Under the law's provisions, businesses of any size or type requiring an environmental discharge permit must document current and projected source reduction and recycling as part of their annual fee payment process. A major grant from EPA will allow detailed inspection of monitoring data to identify local, state, and regional trends and priorities for source reduction.

Legislation passed in Oregon and Massachusetts in 1989

Going beyond voluntary reduction efforts, these laws mandate industrial planning to reduce the use of toxic chemicals.[76] Their provisions include (1) language that places highest priority on reduction of toxic chemicals, rather than off-site recycling or

waste management; (2) a multimedia approach that avoids transferring pollution from one media to another; (3) a requirement for certain industries to develop reports on the use and manufacture of toxic substances and to develop reduction plans and performance goals; (4) provisions to help ensure compliance with planning requirements; (5) expanded technical assistance and research programs; (6) measures to safeguard the privacy of industrial operations; and (7) new generator fees to support program requirements and to further encourage toxic use reduction.

New cross-media structure of the Massachusetts Department of Environmental Protection (DEP)

In the first major reorganization of its type in the nation, this environmental regulatory agency has revamped its conventional, media-based program structure, including air pollution and water pollution, to one that treats resources and industrial facilities as integrated units.

Three main DEP bureaus were created in 1989. The Resource Protection Bureau brings together programs for water pollution control, public drinking water, and wetlands, allowing staff to treat water as an integrated resource. A Waste Prevention Bureau brings together hazardous waste, solid waste, air quality, industrial wastewater, and state right-to-know programs to consolidate all aspects of permitting. This shift from "one pipe at a time" regulation to an integrated facility context is instrumental in preventing the transfer of wastes from one media to another. A Waste Site Cleanup Bureau contains all programs needed to manage sites already contaminated from pollution.

Agency officials are enthusiastic about the benefits already apparent from a reorganization that embodies the cross-media focus of pollution prevention. For example, officials and industry alike are hopeful that program integration will pave the way for regulatory reform that will simplify and coordinate the permitting process. The DEP-industry partnership may be one reason why the Toxics Use Reduction Act passed the Massachusetts legislature without a single vote of opposition.

Local Initiatives

Efforts by local governments, environmental organizations, and other public interest groups often serve as the impetus for state and federal programs. For example, many state waste reduction programs grew out of the responses to local controversies on the siting of hazardous waste facilities. Several examples from California and other states demonstrate this point:

- **Waste Reduction Audits.** Ventura County sent teams of inspectors into various manufacturing plants to conduct waste reduction audits and make recommendations to company officials. From 1985 to 1987 the program resulted in an estimated 70-percent reduction in the volume of hazardous waste going to land disposal.[77] A follow-up survey produced useful information. For example, managerial resistance to new waste reduction techniques and lack of information on alternatives were judged to be major obstacles to waste reduction initiatives.[78]

- **Award of Excellence.** In the spring of 1989, Los Angeles Mayor Tom Bradley presented the first Mayor's Award of Excellence for Outstanding Achievement in Pollution Prevention to a California paint company. Among other accomplishments, the award recipient eliminated an annual generation of 1,000 tons of hazardous waste and achieved a 50-percent reduction in disposal of dirty cleaning solution by using a longer-lived substitute solution. This type of award or recognition program is being used increasingly at the local and state level to provide incentives for pollution prevention.

- **Proposition 65.** Notwithstanding the controversies surrounding California's Proposition 65, there is little doubt that this voter initiative has stimulated discussion of pollution prevention as a way for businesses to avoid unanticipated restrictions on their waste emissions in the future.

■ **Citizen Initiatives**. Such actions are powerful tools for bringing potentially recalcitrant parties to the negotiating table. For example, Oregon and Massachusetts chapters of the Public Interest Research Group (PIRG) were instrumental in bringing about compromise legislation for toxic use reduction. In both states, the PIRGs had initiative petitions and legislative proposals underway that were more restrictive than the final legislation endorsed by all sides.

Finally, public involvement in pollution prevention has been stimulated at the local level through implementation of Title III of the Superfund Amendments and Reauthorization Act (SARA), the title also known as the Emergency Planning and Community Right-to-Know Act. Under section 313, companies with 10 or more employees using or manufacturing certain quantities of over 300 toxic chemicals were required to file Toxic Chemical Release Inventory (TRI) forms with EPA and the appropriate state agency by July 1, 1988. In all, 74,000 reports were submitted by more than 19,000 facilities. After summary reports of the resulting data were released, a detailed computerized national inventory was made available to the public in June 1989.

The implications for increased citizen awareness and involvement are significant, particularly as access to the information becomes readily available through reports and computer access. As EPA Administrator William Reilly announced:

> *The public has played a major role in environmental protection in the past. This new inventory of toxic chemical releases will strengthen the citizen role. . . . Public access to these crucial data is a breakthrough that will facilitate citizen involvement in assessing the risks of toxic chemicals and development of community strategies to prevent pollution.*[79]

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January 30, 1990

Within 10 days of taking office, the new Administration of President George Bush made clear its commitment to the international environment. Secretary of State James A. Baker III, in opening remarks to an international meeting to discuss global climate change, quoted President Bush:

"We face the prospect of being trapped on a boat that we have irreparably damaged—not by the cataclysm of war, but the slow neglect of a vessel we believed to be impervious to our abuse."

The Secretary of State made four points. First, the nations of the world can probably not afford to wait until all the uncertainties regarding climate change have been resolved before they act. Second, while scientists refine current knowledge, nations should focus immediately on prudent steps that are already justified on grounds other than climate change. These include reductions in chlorofluorocarbon (CFC) emissions, greater energy efficiency, and reforestation. Third, whatever global solutions to climate change are considered, they should be as specific and as cost-effective as possible. And fourth, those solutions will be most effective if they reconcile the transcendent requirements for both economic development and a safe environment.

Those words not only announced the strong commitment of the new Administration to the environment, but they also reflected the remarkable international progress made over the last 20 years to protect the global environment. There is now worldwide recognition that many environmental problems demand international solutions, and that both problems and solutions are related to individual behavior. Environmental problems are now addressed cooperatively by governments at the highest levels and within a growing number of international organizations.

CHAPTER 7

International Issues

Environmental quality is an important component of foreign policy today. In the United States and worldwide, there is heightened sensitivity to local, national, and international actions that can affect the environment. Without adequate international environmental management, there can be no guarantee of the continued availability of those living and natural resources necessary to sustain populations, communities, and nations.

The environment is now viewed by many from the perspective of the complex ecosystems that support life on the planet. As the government leaders attending the 1989 Paris Economic Summit stated:

> *There is growing awareness throughout the world of the necessity to preserve better the global ecological balance. This includes serious threats to the atmosphere, which could lead to future climate changes. We note with great concern the growing pollution of air, lakes, rivers, oceans and seas; acid rain, dangerous substances; and the rapid desertification and deforestation. Such environmental degradation endangers species and undermines the well-being of individuals and societies.*[1]

The breadth of international environmental issues spans concerns as diverse as air quality, water quality, ocean dumping, climate change, protection of the ozone layer, biological diversity, the export of hazardous wastes, international trade, and economic development.

Twenty years ago the first annual report to the Congress from the newly created Council on Environmental Quality (CEQ) included an international chapter that discussed transboundary pollution problems, issues that remain critically important today. It stated:

> *Environmental problems do not stop at national frontiers, or ideological barriers. Pollution in the atmosphere and oceans taints all nations, even those benignly favored by geography, climate or natural resources. International cooperation is necessary on many environmental fronts as environmental effects cannot be effectively treated by unilateral action alone. Air and water pollution are not the only environmental problems that have international aspects. Some world resources such as seabed minerals and ocean fish can be wisely dealt with only by international agreement.*[2]

The late 1960s and early 1970s saw a growing awareness in the United States and elsewhere that pollution and exploitation of natural resources were linked to broader economic issues, and that urgent environmental problems required immediate national attention. Pollution concerns in countries outside of the United States included:

- Air and inland water pollution in the United Kingdom,
- Concern over the integrity of water, soil, and other natural resources in the Soviet Union, and
- Air pollution control programs in Japan.

Serious pollution problems also were evident in developing countries like Singapore, Indonesia, Malaysia, Yugoslavia, Mexico, and countries in Central and South America. At the same time there was increasing recognition that certain environmental

problems do not respect national boundaries, and that international cooperation would be required to address such problems.

The international community responded by establishing entities aimed principally at environmental protection. For example, after the Stockholm Conference on the Human Environment in 1972, the U.N. General Assembly established the U.N. Environment Program (UNEP). In 1970 the Organization for Economic Cooperation and Development (OECD) established an Environment Committee dedicated to harmonizing policies for international environmental policy. In 1972 the European Community launched its first action program for the environment.

Since the Stockholm Conference in 1972, a growing consensus has recognized pollution as not only a problem in need of abatement actions, but also a symptom of an economic development approach in need of broad economic and social adjustments. Environmental issues cannot be addressed in isolation from problems of population and economic development. Economic and trade policies are significant influences on human behavior, and they can contribute directly to environmental degradation. Human and natural resource management must be included as important elements of economic development.

The crescendo of environmental concern over the last two decades has now led world leaders and institutions to consider environmental issues in terms of broad national and international policies. It is no longer unusual for national leaders, alone or in concert, to speak out regarding global environmental concerns and press for actions that benefit the entire world and not simply a single sovereign nation or region.

In retrospect, it is not surprising that at the end of the 1960s only a third of the international environmental agreements that exist today were then in effect, and those were principally addressed to migratory fish and game or to prevention of ocean pollution. Few science and technology agreements were in effect. The international sharing of scientific and technical information then did not compare to the networks of scientists and organizations that today work in global teams linked by electronic communications. Similarly, the international capacity to relate science and technology with economics and trade and to understand integrated global ecological systems has been vastly increased.

It is difficult to overstate the extent to which international environmental cooperation has become integrated with economic, trade, science, and technology issues, and the panoply of other forces that bear on sound environmental practices and enhance living conditions. For example, international scientific organizations are studying pollutants that degrade the global environment, and they are developing the response strategies to help protect it. Improved scientific understanding of complex ecological interrelationships has helped to blur the distinction between international and domestic concerns. It is now understood that local or regional economic activities may have serious international consequences from direct, indirect, or cumulative environmental effects. For example, economic development that contributes to a loss of species, even within a relatively small region of the world, may have broad international implications.

The past decade has seen the growing worldwide acceptance of the concept of "sustainable development" as the basis for a more rational use of world resources. The concept has broad appeal. No longer can the issues of economic development and the environment be considered independently. Furthermore, the economic needs of developing countries are being, and will have to be increasingly, addressed by international organizations and international environmental agreements. For example, the 1987 Montreal Protocol on Substances which Deplete the Ozone Layer made allowances for the needs of developing countries. Discussions taking place today within the U.N. Intergovernmental Panel on Climate Change also recognize the need to encourage developing countries to adopt newer, more environmentally sound technologies.

An important facet of economic development is the transfer of technology, in the form of both information and materials. The concept of sustainable development incorporates the notion of stewardship and responsibility to future generations, and it calls on industrialized nations to encourage and assist developing nations to acquire and incorporate newer, environmentally sound technology.

The international environmental movement has come at a time of significant increase in international free trade. Twenty years ago the costs of pollution control were sometimes seen as a handicap in international trade. Countries that imposed such

costs would be at a competitive disadvantage, unless international agreements provided a level playing field. As the 1970 CEQ Annual Report stated:

> *What nations do to clean up domestic pollution can affect international commerce. The cost of pollution control can change the competitive position of a nation's industry. And how nations regulate international transportation and imports to eliminate sources of pollution can also have profound bearing on trade.*[3]

Yet today there is reason to believe that growth in free trade and improved international environmental management practices are not incompatible. Expanded international markets encourage participating nations to sell products and develop technologies that can meet international standards for environmental safety.

Since 1970 international trade has grown substantially, as has the emphasis on regulations controlling the import and export of goods that are not considered environmentally safe. Since standards that are designed to protect human health and the environment can be nontariff barriers to trade when they vary among countries, trading partners may have an incentive to develop uniform environmental standards and to adopt similar data requirements.

In some instances, however, a country may enforce more stringent environmental standards than another because of differences in natural or social conditions. For example, some trade goods can pose health hazards that are almost impossible to identify anywhere but at the point of manufacture and certainly prior to export. Thus, for example, the United States restricts the export of certain hazardous materials. U.S. law may require either notification or specific acceptance from the recipient country prior to export out of the United States.

Similarly, the United States must depend upon reliable environmental controls abroad in helping avoid the import of goods that pose environmental hazards. The concept of notification and consent by importers of pesticides and hazardous materials has become increasingly accepted in the last several years. For example, the Basel Convention uses a notification and consent scheme to control transboundary traffic in hazardous and other

wastes. UNEP and the U.N. Food and Agriculture Organization (FAO) recently have adopted nonbinding prior informed consent schemes in the areas of trade in chemicals and pesticides, respectively. OECD also has developed an information exchange program.[4]

Historical Perspective

High-level intergovernmental conferences addressing a range of environmental concerns are common today. However, they were without precedent in 1970. The 1972 Stockholm U.N. Conference on the Human Environment was the first such meeting, and its organizers had to establish both the process and the focus for an international environmental conference. Yet the Stockholm Conference provided for the international community a statement of environmental concern and direction comparable to that demonstrated in the United States by enactment of the National Environmental Policy Act of 1969.

From the perspective of almost 20 years, the significance of the Stockholm Conference may not be appreciated fully. Yet in many respects the conference and the planning process that preceded it were unique at the time. They were effective in stimulating both environmental awareness and international diplomatic action.

As CEQ stated in its 1985 annual report:

> *The success of the Stockholm Conference was largely due to the extensive and thorough preparations made for it. Four Preparatory Committee meetings as well as a range of regional and scientific gatherings were held. International and national nongovernmental organizations, especially the International Union for the Conservation of Nature and Natural Resources and the International Council of Scientific Unions (ICSU), helped develop declarations and recommendations.*[5]

The conference had its origin in a December 1968 U.N. General Assembly resolution, a Swedish initiative, calling for a world conference on the human environment. It required four years of development by a 27-nation preparatory committee. At the conference, 133 nations, many of which had addressed their own environmental issues for the first time as part of their preparation for the conference, agreed upon 109 action recommendations and issued a Declaration on the Human Environment.[6] That Declaration, in effect a charter of fundamental environmental rights and duties, while not legally binding, still serves as a basis for international environmental law. Among other things, it stated:

> *The protection and improvement of the human environment is a major issue which affects the well-being of peoples and economic development throughout the world; it is the urgent desire of the peoples of the whole world and the duty of all Governments.*
>
> *Man has a special responsibility to safeguard and wisely manage the heritage of wildlife and its habitat, which are now gravely imperilled by a combination of adverse factors. . . .*
>
> *States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.*
>
> *States shall cooperate to develop further the international law regarding liability and compensation for the victims of pollution and other environmental damage caused by activities within the jurisdiction or control of such States to areas beyond their jurisdiction.*[7]

The 109 recommendations of the Stockholm Conference can be grouped into five areas: human settlements, natural resources management, pollutants, education, and development. The recommendations were submitted to and approved by the U.N. General Assembly at its 1972 fall session. The Declaration noted

the need for a common outlook and for common principles to inspire and guide all nations in the preservation and enhancement of the human environment. It further noted that a growing class of environmental problems, because they were regional or global in extent or because they affected common international resources, required extensive cooperation among nations and actions by international organizations in the common interest.[8]

A key result of the conference was establishment of UNEP, a permanent U.N. body that coordinates international environmental activities. Located in Nairobi, Kenya, UNEP became the first U.N. body to be based in the developing world.

The concept of "human environment" was especially important. In contrast to previous characterizations of the natural environment as being distinct from the realm of human needs, the concept of "human environment" recognized the necessity, especially in the developing countries, of action to alleviate overpopulation, poverty, and hunger. The conference motto, "Only One Earth," also spoke to the interdependence of species and peoples. To some, it seemed that the community of nations, with new concern for and loyalty to the planet, was moving toward new possibilities:

> *But possibly it is precisely this shift of loyalty that a profound and deepening sense of our shared and interdependent biosphere can stir to life in us. That men can experience such transformations is not in doubt. From family to clan, from clan to nation, from nation to federation—such enlargements of allegiance have occurred without wiping out our earlier loves. Today, in human society, we can perhaps hope to survive in our prized diversity provided we can achieve an ultimate loyalty to our single, beautiful, and vulnerable planet Earth.*[9]

In retrospect, the legacy of the Stockholm Conference may be considered to consist of a number of elements. These include involving governments around the world in the process of environmental assessment and planning, uniting developed and developing nations in a common concern for the planet, encouraging private sector participation in governmental processes,

developing a list of environmental priorities and principles, establishing an international environmental agency, and promoting a number of major new initiatives, including treaties and further international conferences to address problems first raised at Stockholm.

Stockholm spawned an approach to environmental issues through large U.N.-sponsored international conferences that explored special concerns. In the style of Stockholm, these meetings—which solicited broad participation by governments and nongovernmental organizations—developed action plans that highlighted international cooperation through international organizations.[10] In the 1970s and 1980s the U.N. system convened several such meetings, including treaty negotiations. (See Table 7-1.)

Table 7-1.—Major Specialized Environmental Conferences Sponsored by the United Nations, 1974–89.

DATE	CONFERENCE	LOCATION
1974	World Population Conference	Bucharest, Romania
	World Food Conference	Rome, Italy
1976	Human Settlements Conference	Vancouver, Canada
1977	UNESCO/UNEP Intergovernmental Conference on Environmental Education	Tbilisi, USSR
	U.N. Water Conference	Mar del Plata, Argentina
	U.N. Conference on Desertification	Nairobi, Kenya
	World Conference on the Ozone Layer	Washington, D.C., USA
1979	Conference on Science and Technology for Development	Vienna, Austria
1981	U.N. Environment Program Senior Officials Meeting on Environmental Law	Montevideo, Uruguay
	Conference on New and Renewable Sources of Energy	Nairobi, Kenya
1982	U.N. Environment Program Session of Special Character	Nairobi, Kenya
1984	U.N. International Conference on Population	Mexico City, Mexico
1985	Vienna Convention on the Protection of the Ozone Layer Diplomatic Conference	Vienna, Austria
1987	Montreal Protocol Diplomatic Conference on Protection of the Ozone Layer	Montreal, Canada
1988	Intergovernmental Panel on Climate Change	Geneva, Switzerland
1989	Basel Convention on Transboundary Movement of Hazardous Wastes Diplomatic Conference	Basel, Switzerland

Stockholm also left a legacy that called for periodic reexamination of environmental issues. A 20-year anniversary conference is scheduled for 1992 in Brazil. At a 10-year follow-up

conference in 1982, governments from 105 countries convened in Nairobi, Kenya. The Nairobi conference demonstrated the maturation of global environmental awareness and a greater recognition of the importance of economic development. In a chapter describing the Nairobi "Special Session," the CEQ 1982 Annual Report stated:

> *The conference revealed that over the last decade major shifts had taken place in attitudes, interest and priorities regarding environmental issues. In 1972, most countries were enjoying relative economic well-being and stability. The mood at Stockholm was upbeat, with attention largely focused on control of air and water pollution and protection of wildlife and unique ecosystems, and on actions that governments could take in these areas. The backdrop to the 1982 conference was quite different. Serious economic difficulties and uncertainties were affecting both rich and poor countries. Primary interest had shifted from pollution control and resource protection to "sustainable development," a concept embracing economic growth and environmental quality as "two heads of the same coin." More attention was paid at the Nairobi conference to generating action at the local rather than at the national level and by engaging greater participation of institutions outside government, including business, and industry.*[11]

The 1982 Nairobi conference reiterated concerns on issues that remain important today, including:

- Atmospheric problems such as deteriorating urban air quality, increased carbon dioxide (CO_2) concentrations in the atmosphere, and depletion of stratospheric ozone;
- Ocean pollution from oil and other substances;
- Surface water and groundwater contamination; and
- Degradation of terrestrial biota and bioproductive systems.

The "Nairobi Declaration" themes included the need for environmental assessment and management and for environmentally sound and sustainable socioeconomic development.[12]

International Issues Today

The environmental issues that concern the world today are being addressed by a number of international organizations and by international agreements in effect between and among nations.

International Organizations

In 1989 international organizations represented a major voice for the environment. These organizations, designed to transcend national interests, address fundamental economic and other forces that influence the quality of the human environment. Special environmental units of international organizations have been established. The U.N. Environment Program, for example, is dedicated solely to environmental issues.

Twenty years ago these dedicated environmental entities did not exist, although in 1970 an array of international organizations had selective involvement in environmental issues. In fact, many of those early organizations, shown in Table 7-2, are important environmental leaders today. Other international organizations, including various other United Nations entities, the World Bank Group, and the regional development banks, are becoming increasingly involved in the environmental impacts of their activities. Moreover, other regional organizations such as the Organization for Economic Cooperation and Development (OECD) and the European Community (EC), have created environmental components to ensure that environmental considerations are part of their organizational considerations.

Establishment over the past 20 years of international environmental organizations reflects a global maturation of a governmental commitment to a worldwide approach to environmental management. These international organizations seek to

Table 7-2.—Environmental Activities of International Bodies, 1970.

AGENCY	PROGRAMS
UNITED NATIONS	
Economic Commission for Europe	Air and Water Pollution Control; Urban Development
Intergovernmental Maritime Consultative Organization (International Maritime Organization)	Information on Oil Spill Control; Development of International Controls Over Marine Pollution
U.N. Educational, Scientific, and Cultural Organization	Scientific Studies on Changes in Oceans; Development of Man and the Biosphere Program
U.N. Development Program	Resource Surveys, Conservation Projects, Ecological Studies, Training Programs
U.N. Scientific Committee on the Effects of Atomic Radiation	Technical Reports on Levels of Natural and Man-Made Radioactivity in the Environment
International Labor Organization	Studies and Standards for Occupational Health
World Health Organization	Definition of Environmental Standards for Human Health; Identification of Environmental Hazards—Air, Water, Soil, and Food Pollution, such as Pesticides; Study of Effects of Induced Changes in the Environment, such as Rapid Population Changes, Massive Migration, Industrialization
Food and Agriculture Organization	Conservation Aspects of Soil, Forests, and Terrestrial Waters; Studies on Water Quality Criteria for Fish; Pulp and Paper Mill Effluents; Sewage Effluents
World Meteorological Organization	World Weather Watch Information Related to Air Pollution and Maritime Pollution
International Civil Aviation Organization	Aircraft Noise
International Atomic Energy Agency	Pollution from Radioactive Substances
U.N. Conference on the Human Environment	Preparatory Work for the 1972 Stockholm Conference
World Bank Group	International Bank for Reconstruction and Development, International Development Association, International Finance Corporation
Regional Development Banks	African Development Bank, Inter-American Development Bank, Asian Development Bank, Caribbean Development Bank
OTHER INTERGOVERNMENTAL BODIES	
NATO Committee on Challenges of Modern Society	Disaster Assistance, Air Pollution, Open-Water Pollution, Inland Pollution, Environment in the Strategy of Regional Development

Table 7-2.—Environmental Activities of International Bodies, 1970 (cont.).

AGENCY	PROGRAMS
Organization for Economic Cooperation and Development	Water Resources Management, Air Pollution, Pesticides, Organizing an Environmental Division
Organization of African Unity	Serves as the Depository for the African Convention on the Conservation of Nature and Natural Resources
Organization of American States	Latin American Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere
Council of Europe	Information Sharing Pollution Control, Ecology
European Communities	European Economic and Social Cooperation
NONGOVERNMENTAL ORGANIZATIONS	
International Council of Scientific Unions	International Biological Program
International Union for Conservation of Nature and Natural Resources	Ecology, Species Survival, National Parks, Education, Environmental Policy
The World Wildlife Fund	Ecological Consequences of International Development

promote international environmental awareness, develop tools for environmental monitoring and testing, and promote common management practices that protect natural and biological resources, sometimes through international agreements. Because these organizations attempt to influence population policies, economic growth, trade, technology development, and other factors that affect environmental quality, their actions sometimes can be controversial, particularly since they may challenge particular policies of individual governments. Yet these young institutions have achieved remarkable results.

The existence of international environmental organizations, however, has not completely satisfied the need for special temporary arrangements that focus additional resources on special concerns. For example, in December 1983 the United Nations established the World Commission on Environment and Development (WCED) to examine carefully the relationship between environment and development. In November 1988 the U.N. Environment Program and the World Meteorological Organization (WMO) formed the Intergovernmental Panel on Climate Change (IPCC) to examine the science of climate change, its economic and social impacts, and possible response options.

United Nations Programs

The United Nations has played an increasingly important role in international environmental issues over the past 20 years. The United Nations, established in 1945, is headed by a Secretary General. Its principal bodies include the General Assembly, the Security Council, and the Economic and Social Council. Specialized agencies, autonomous organizations, and programs also conduct environmental activities. Because of the importance of environmental issues today, competition exists among the General Assembly and other U.N. components to provide leadership on particular environmental initiatives.

U.N. Environment Program

Today UNEP is a major international advocate for environmental management. It is a catalytic and coordinating body for environmental activities within the United Nations system and among international organizations, scientists, and environmental groups. Its mandate includes the assessment, monitoring, and protection of the human environment and the promotion of environmentally sound economic and social development in both rural and urban areas. Relatively small, it has approximately 180 professional staff, supported annually by $5 million in U.N. funds and $40 million in voluntary contributions from 65 governments. A UNEP Governing Council of 58 nations is elected on a rotating basis by the U.N. General Assembly.

Within recent years UNEP has emphasized the formulation and negotiation of international agreements relating to the environment. For example, under its Regional Seas Program, UNEP has fostered a series of regional agreements for protection of the marine environment. More recently, UNEP sponsored negotiations that culminated in the 1985 Vienna Convention for Protection of the Ozone Layer. Likewise, UNEP was instrumental in developing the ensuing related Montreal Protocol. In 1989 UNEP-organized negotiations for the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal reached a final agreement. Concerns about climate change and biological diversity have stimulated UNEP

activities for developing new international conventions in these areas.

UNEP programs include global environmental monitoring, development of regional environmental action plans, and support for international environmental law, public information, industry and environment information, education, and training. Worldwide monitoring and assessment is a major activity. For example, the Global Environmental Monitoring System (GEMS) collects, stores, retrieves, analyzes, and disseminates environmental data related to a range of potential pollutants. The International Register of Potentially Toxic Chemicals (IRPTC) collects, validates, and exchanges information on hazardous chemicals. The International Referral System for Sources of Environmental Information (INFOTERRA) assists governments, organizations, and individuals to locate technical and scientific information on the environment.

Priority areas for UNEP action include:

- Atmospheric issues—climate change, ozone layer depletion, transborder air pollution, and acid rain;
- Freshwater—supply and quality;
- Oceans and coastal areas—pollution and coastal zone management;
- Land degradation—desertification, deforestation;
- Loss of biological diversity; and
- Hazardous waste and toxic chemicals.

World Commission on Environment and Development

Ten years after the Stockholm Conference fostered the concept of "Only One Earth" where interdependent species shared the same environment, the 1982 Nairobi conference advanced the concept of sustainable development. In the fall of 1983, the U.N. General Assembly passed a resolution that led to establishment of the World Commission on Environment and Development (WCED)

and urgently called for formation of long-term environmental strategies to achieve sustainable development by the year 2000 and beyond. Gro Harlem Brundtland, then Prime Minister of Norway, was named to chair the WCED, and Mansour Khalid from Sudan was named vice-chairman. They appointed the remaining 21 members, more than half from developing countries.

International efforts to address the environmental concerns of the 1990s undoubtedly will reflect the influence of WCED. The World Commission made a singular contribution to the environmental dialogue of the 1990s by reviewing the condition of the globe and its economy from the perspective of the sustainability of the ecosystems on which the global economy depends. It made recommendations on how economic costs can be borne equitably, how the global commons can be appropriately and equitably managed, and how security as traditionally understood—in terms of political and military threats to national sovereignty—can be expanded to include the growing impacts of environmental stress.

At its inaugural meeting in Geneva on October 1-3, 1984, the WCED adopted the following mandate:

- Re-examine the critical issues of environment and development and formulate innovative, concrete, and realistic action proposals to address them;
- Strengthen international cooperation on environment and development and assess and propose new forms of cooperation that can reshape existing economic patterns and influence policies and events in the direction of needed change; and
- Raise the level of understanding and commitment to action on the part of individuals, voluntary organizations, businesses, institutions, and governments.[13]

Between 1985 and 1987, the WCED conducted public hearings in a dozen cities around the world. Hundreds of organizations and individuals gave testimony, and many others gave written submissions. To provide further information, several advisory panels were established.

In 1987 the WCED published its report, *Our Common Future*. That report argued that the environmental consequences of population increases and economic development have become intertwined. The development of the global economy and the protection of the global ecology may appear to be separate issues, but they are, in fact, different facets of the same problem. As *Our Common Future* states:

> *Until recently, the planet was a large world in which human activities and their effects were neatly compartmentalized within nations, within sectors (energy, agriculture, trade), and within broad areas of concern (environmental, economic, social). These compartments have begun to dissolve. This applies in particular to the various global 'crises' that have seized public concern, particularly over the last decade. These are not separate crises: an environmental crisis, a development crisis, an energy crisis. They are one.*[14]

Our Common Future defines the concept of sustainable development in very simple terms: humanity has the ability to make development sustainable—to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.[15] The concept, however, is not rigid; it can be interpreted flexibly depending on scientific, social, economic, and political circumstances. Moreover, such circumstances help define how the costs of sustainable development are to be characterized, and ultimately how the costs are to be borne.

The WCED report stressed that international efforts to protect the environment in the 1990s must include several specific issues:

- Population and its effect on natural resources and economic development, including (1) food security—making food available where needed; (2) species and ecosystems—maintaining biological diversity; and (3) energy—energy efficiency and conservation of energy sources;

- Industry—use of less environmentally invasive technologies; and
- Urban challenge—proper planning and development of cities and establishment of settlement practices.

As a follow-up to the WCED report, the United States and other Economic Commission for Europe (ECE) countries will meet at Bergen, Norway, in May 1990. The U.N. General Assembly endorsed the WCED statement that sustainable development should become a guiding principle of the United Nations, individual governments, and private institutions, organizations, and enterprises.[16] In addition, the General Assembly welcomed follow-up activities such as national, regional, and global conferences.

The Bergen conference, titled "Action for a Common Future," intends to review progress related to selected aspects of the Brundtland Commission report and further action specifically relevant to the ECE region. The main topics for discussion will be sustainable development, sustainable energy use, sustainable industrial activity, and public awareness. ECE governments have been requested to host workshops on specific topics.

The United States hosted a workshop in January 1990 on the Economics of Sustainable Development that sought the following actions:

- Establish basic economic definitions and conditions of sustainable development in industrial and developing countries; and
- Identify key economic policy and institutional changes within the power of developed and developing countries that will promote sustainable development both at home and internationally.

Other workshops were on Sustainable Industrial Activity, hosted by Poland; Sustainable Energy Use, hosted by the Federal Republic of Germany; and Awareness Raising and Public Participation, hosted by the United Kingdom.

Economic Commission for Europe

U.N. regional economic commissions are charged with strengthening economic and other forms of cooperation among their members. These economic commissions include the Economic Commission for Europe (ECE), the Economic Commission for Africa (ECA), the Economic and Social Commission for Asia and the Pacific (ESCAP), the Economic Commission for Latin America and the Caribbean (ECLAC), and the Economic and Social Commission for Western Asia (ESCWA). Since the 1970s all the commissions have increasingly involved the environment as an integral part of economic development. The United States is a member of ESCAP, ECE, and ECLAC.

The Economic Commission for Europe (ECE) includes nations from Eastern and Western Europe, as well as the United States and Canada. ECE is probably the most advanced of the five U.N. regional economic commissions in terms of environmental activities, since it involves mainly developed countries. The role of ECE in environmental issues is considered a model for other regional economic commissions. Since the ECE includes the United States, the Soviet Union, and members from both western and eastern Europe plus Canada, it serves as an important forum for East-West cooperation on environmental issues.

Even in 1970 ECE had more than 10 years of experience dealing with water pollution and 20 years of experience in city and urban environmental issues. In 1973 it established a group of senior advisors on environmental issues. Through the work of this group, ECE has adopted a varied work program addressing such subjects as air pollution, energy, water pollution, toxic wastes, transportation, tourism, and transborder Black Sea pollution.

ECE studies related to the long-range transport of air pollutants, begun in 1977, led to the 1979 Convention on Long-Range Transboundary Air Pollution (LRTAP) and subsequent protocols. In the 1980s the ECE recognized the importance of conducting environmental impact assessments, and it has taken steps to develop a multilateral agreement for transboundary environmental impact assessment.

Intergovernmental Panel on Climate Change

Global climate change is a major international environmental issue today. International concern about the "greenhouse effect," the possible increase in global climate temperature because of changes in the composition of the earth's atmosphere, has escalated in the 20 years since its brief mention in the first annual report of the Council on Environmental Quality.[17] Yet the possible extent of climate change and its likely effects on the environment are both complex and controversial. Nations are beginning to take the threat of climate change seriously. Moreover, they are studying the need to modify human activity, which may be a major cause of climate change.

Because of the scientific uncertainties associated with assessing potential climate changes, the international scientific community has become increasingly involved in the issue. For example, the 1978 World Climate Conference led the World Meteorological Organization (WMO) to establish a World Climate Program that considers the role of CO_2 and its possible impacts on human activities. Other discussions have been held by WMO, UNEP, and the International Council of Scientific Unions (ICSU)[18] at various international scientific meetings held worldwide.

In 1987 discussions within the U.N. General Assembly led to requests by the governing bodies of WMO and UNEP to establish an intergovernmental mechanism to address the science of climate change, the potential environmental, economic, and social impacts of climate changes, and possible national and international responses to such changes. As a result, the Intergovernmental Panel on Climate Change (IPCC) was established. The first meeting of the IPCC took place in Geneva, November 9-11, 1988. Approximately 35 countries, including the United States, Japan, the Soviet Union, and several international organizations attended. Both the Secretary General of WMO and the Executive Director of UNEP underscored the importance of the IPCC in light of U.N. General Assembly interest. The General Assembly requested that the interim report of the IPCC be delivered by September 1990.

IPCC agreed that its main tasks were the following:

- Assess available scientific information on climate change;
- Assess environmental and socioeconomic impacts of climate change; and
- Formulate response strategies.

IPCC organized its efforts under three working groups with designated chairs, vice-chairs, and core members, although all other nations were allowed to participate in working groups as they chose without regard to "core" designation. The organization of IPCC is shown in Figure 7-1.

IPCC working groups have the following charges and officers:

■ **Working Group I, Research.** Review the state and knowledge of the science of climate and climate change with special emphasis on global warming. Chair, UK; Vice-chairs, Brazil and Senegal.

■ **Working Group II, Impacts.** Review programs and conduct studies of social and economic impacts. Chair, USSR; Vice-chairs, Australia and Japan.

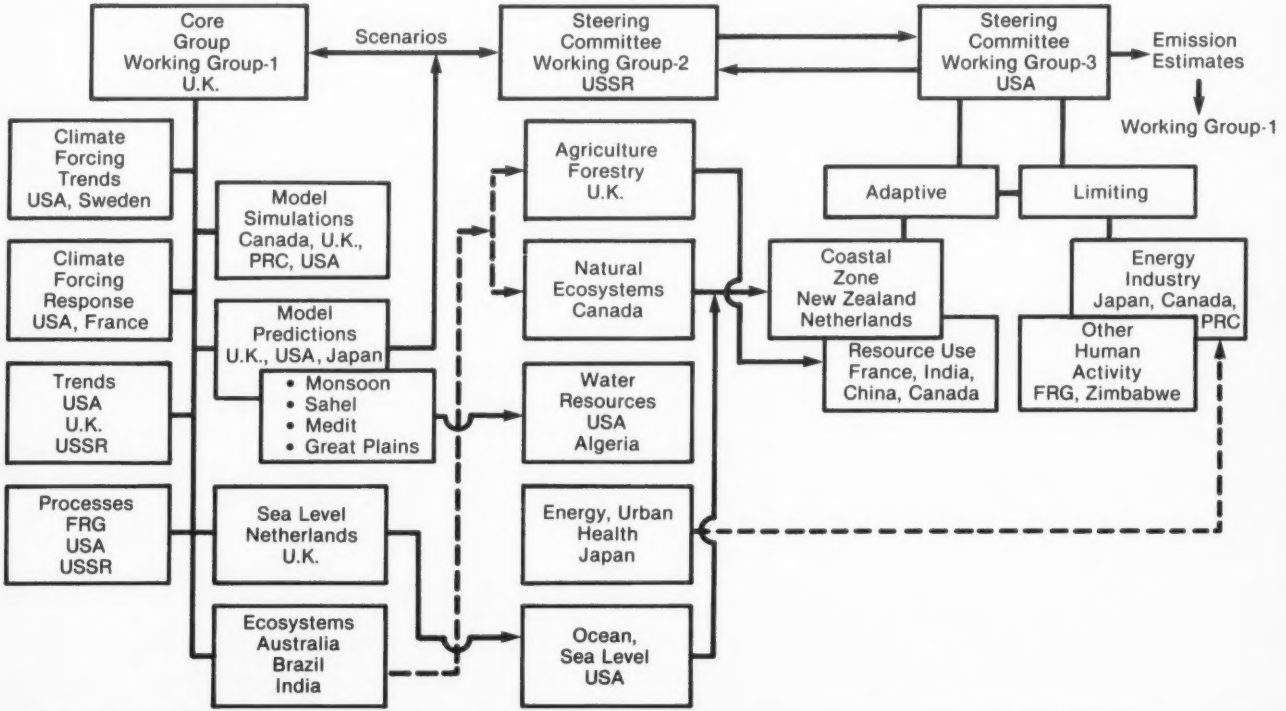
■ **Working Group III, Policy.** Develop and evaluate possible policy responses by governments to delay or mitigate the impact of adverse climate change. Chair, USA; Vice-chairs, Canada, China, Malta, Netherlands, and Zimbabwe.

Each working group has a set of tasks that, when completed and integrated, will form the text of the IPCC Interim Report. That report should be completed by the fall of 1990.

■ **Working Group I**, chaired by the United Kingdom, has divided its scientific review into several different areas:

- Greenhouse gases and other forcing agents;
- The relative importance of climate forcing agents;
- Potential effects;

Figure 7.1—Interactions of Subgroups within the Intergovernmental Panel on Climate Change (IPPC).



Note: FRG = Federal Republic of Germany PRC = Peoples Republic of China

- Mathematical and process models;
- Transient climate simulations, 1850-2100;
- Climate observations, 1850-1989 and the last 1000 years;
- Detecting climate change;
- Sea level rise; and
- Effects on ecosystems.

Working Group I is also responsible for devising methods by which the effect on climate of reductions in one greenhouse gas could be compared with similar reductions in another greenhouse gas.

■ **Working Group II**, chaired by the Soviet Union, has divided its work on effects into the following areas:

- Agriculture, forestry, and land use;
- Natural terrestrial ecosystems;
- Hydrological water resources;
- Energy, industry, transportation, human settlements, and the urban environment; and
- World oceans and coastal zones.

■ **Working Group III**, chaired by the United States, is assessing policy and technology responses to climate change and measures to implement such responses, including the elements of a framework convention on climate change. The steering committee has two particular tasks. First, it is responsible for developing emissions scenarios that can be used by the working groups. Emissions scenarios describe different possible climate changes depending on different assumptions for changes in greenhouse gas emissions. Thus, they cover the range of response options that need to be considered.

The second task of Working Group III is to develop and analyze implementation mechanisms, such as legal and institutional measures, public education and information, technical as-

sistance, economic and market measures, and financial measures. Implementation mechanisms are the actions that governments can take to stimulate changes in behavior that will lead to the reduction or limitation of greenhouse gas emissions or the adaptation to changes in climate.

In October 1989 the Response Strategy Working Group prepared a report on implementation mechanisms and a preliminary description of the possible elements of a climate change convention. This framework convention will provide a means for governments to act to limit emissions of greenhouse gases and provide for development and sharing of scientific and technical information. Development of elements of the framework convention on climate change is now a major goal for IPCC.

Four subgroups make up Working Group III. The Energy and Industry Subgroup (EIS) and the Agriculture, Forestry, and Other Human Activities Subgroup (AFOS) focus primarily on limitation strategies. The Coastal Zone Management Subgroup (CZMS) and the Resource Use and Management Subgroup (RUMS) address adaptation strategies. The Energy and Industry Subgroup (EIS) is addressing the relationship of energy, economy, and greenhouse gas emissions to determine what policies and technologies can make a significant contribution to limiting greenhouse gas emissions.

The Agriculture, Forestry, and Other Human Activities Subgroup (AFOS) is developing response options based on studies of forestry data, forestry response options, and special damage to boreal forests from air pollution and climate stress. Studies on agriculture are focusing on methane and other gas emissions from livestock, rice paddies, and fertilizers. Results of workshops on tropical forests, boreal forests, and temperate forests will be prepared for the Interim Report.

The Coastal Zone Management Subgroup (CZMS) is providing information and options for coastal zone management strategies over the next 10 years. It has prepared papers on the extent and timing of sea level rise; impacts; problem identification; available adaptive options and costs for coastal areas at risk; social, economic, legislative, and other implications of adaptive options; funding mechanisms for adaptation; and inventories of technology and existing laws and policies.

The Resource Use and Management Subgroup (RUMS) addresses the use and management of a variety of natural resource issues. It has drafted papers on the management of water resources, salinization, desertification, forestry, agriculture, fisheries, animal husbandry, unmanaged ecosystems, biological diversity, food and fiber security, and land use in general.

IPCC has established a Special Committee on the Participation of the Developing Countries. This committee has encouraged action that would be especially valuable to developing countries in enabling them to participate more fully in the IPCC. Such actions could include seminars in the developing countries, travel assistance to facilitate their participation in IPCC meetings, financial and technical assistance, and cooperation in research, development, and demonstration programs.

IPCC plans to issue its Interim Report in October before the Second World Climate Conference, scheduled for October–November 1990 in Geneva. It is anticipated that shortly thereafter negotiations for a climate convention will begin. President Bush, in a meeting with Soviet President Gorbachev in Malta in December 1989 and at the Third IPCC Plenary Meeting in February 1990, offered to host the opening round for the climate convention in the United States. IPCC most likely will continue its work at least until the conclusion of a framework convention.

Organization for Economic Cooperation and Development

In addition to U.N. organizations, the United States has given strong support to other international environmental programs, such as those sponsored by the Organization for Economic Cooperation and Development (OECD). Its growth paralleled that of national programs to address environmental degradation in western industrialized countries in the 1970s. OECD became involved with environmental issues in the 1970s because (1) some environmental problems are intrinsically international; (2) the differences in environmental control practices among different countries could have implications for economics, trade, and political relations; and (3) OECD believed that individual

governments were insufficiently prepared to address growing environmental problems. Thus, joint action was necessary.[19]

OECD was established in 1960 as an outgrowth of the 1948 organization set up to administer Marshall Plan funds. Its members are 24 industrialized countries: 19 European countries, Canada, the United States, Japan, Australia, and New Zealand. In addition, the European Community takes part in OECD work, and Yugoslavia participates in many activities. A strong effort to protect the environment is essential, since OECD countries generate about 70 percent of the world's gross domestic product and 70 percent of international trade. Yet they account for only 17 percent of the world's population and less than a quarter of its land mass. Moreover, OECD countries account for 60 percent of the total atmospheric pollution generated by human activities.[20]

The organization is directed by the OECD Council, and it incorporates a number of principal bodies devoted to particular sectoral or substantive issues such as agriculture, energy, trade, science, and technology. Environment has been a growing concern to these principal bodies, each of which can recommend that the OECD Council adopt binding "Decisions of Council" or advisory "Recommendations and Declarations."

One such principal body, the Environment Committee, was formed in 1970 to aid OECD in developing coordinated and harmonized policies for promoting international environmental quality. The work of the committee is carried out by subsidiary groups that address general areas of environmental policy: environment and economics, pollution prevention and control, chemicals, national reviews and environmental information, and urban affairs.

OECD environmental activities include specific recommendations and decisions on the economic, legal, and scientific aspects of environmental management. The "polluter-pays" principle has been accepted by all OECD member countries, as has the concept that "prevention is better than repair." OECD has made recommendations or decisions on noise abatement, water management, transfrontier pollution, and control of international shipments of wastes. It also has developed economic techniques and economic instruments on environmental policy. The extensive list of Council Decisions and Recommendations related to environmental concerns is shown in Table 7-3.

Table 7-3.—Actions of the Organization for Economic Cooperation and Development (OECD) Council Relating to the Environment, 1972–84.

SUBJECT	DATE	ACTION
Environment and Economics	1972	Guiding Principles Concerning International Economic Aspects of Environmental Policies
	1974	Implementation of the Polluter-Pays Principle
Environmental Assessment	1974	Analysis of the Environmental Consequences of Significant Public and Private Projects
	1979	Assessment of Projects with Significant Impact on the Environment
Resource Management		
Air	1974	Guidelines for Action to Reduce Emission of Sulphur Oxides and Particulate Matter from Fuel Combusion in Stationary Sources; Measures Required for Further Air Pollution Control
	1985	Control of Air Pollution from Fossil Fuel Combustion
Water	1971	Determination of the Biodegradability of Anionic Synthetic Surface Active Agents
	1974	Control of Eutrophication of Waters; Strategies for Specific Water Pollutants Control
	1978	Water Management Policies and Instruments
Energy		
	1974	Energy and the Environment
	1976	Reduction of Environmental Impacts from Energy Production and Use
	1977	Reduction of Environmental Impacts from Energy Use in the Household and Commercial Sectors
	1979	Coal and the Environment
	1985	Environmentally Favorable Energy Options and Their Implementation
Waste	1976	Comprehensive Waste Management Policy
	1978	Re-Use and Recycling of Beverage Containers
	1980	Waste Paper Recovery
	1984	Transfrontier Movements of Hazardous Waste
	1985	International Cooperation concerning Transfrontier Movements of Hazardous Waste
	1986	Exports of Hazardous Wastes from the OECD Area
Chemicals	1971	Procedures for Notification and Consultation regarding Measures for Control of Substances Affecting Man and His Environment
	1973	Protection of the Environment by Control of Polychlorinated Biphenyls; Measures to Reduce All Man-Made Emissions of Mercury to the Environment

Table 7-3.—Actions of the Organization for Economic Cooperation and Development (OECD) Council Relating to the Environment, 1972–84 (cont.).

SUBJECT	DATE	ACTION
	1974	Assessment of the Potential Environmental Effects of Chemicals
	1977	Guidelines in respect of Procedures and Requirements for Anticipating the Effects of Chemicals on Man and in the Environment
	1981	Mutual Acceptance of Data in the Assessment of Chemicals
	1982	Minimum Pre-Marketing Set of Data in the Assessment of Chemicals
	1983	Mutual Recognition of Compliance with Good Laboratory Practice; Protection of Proprietary Rights to Data Submitted in Notifications of New Chemicals; Exchange of Confidential Data on Chemicals; OECD List of Non-Confidential Data on Chemicals
	1984	Information Exchange related to Export of Banned or Severely Restrictive Chemicals
Transfrontier Pollution	1974	Principles Concerning Transfrontier Pollution
	1976	Equal Right of Access in Relation to Transfrontier Pollution
	1977	Implementation of a Regime of Equal Right of Access and Non-Discrimination in Relation to Transfrontier Pollution
	1978	Strengthening International Cooperation of Environmental Protection in Transfrontier Regions
	1982	Certain Financial Aspects of Action By Public Authorities to Prevent and Control Oil Spills
State of the Environment	1979	Reporting on the State of the Environment
Transport	1974	Traffic Limitation and Low-Cost Improvement of the Urban Environment
Noise	1974	Noise Prevention and Abatement; Noise Abatement Policies
	1985	Strengthening Noise Abatement Policies
Coastal Zone Management	1976	Principles concerning Coastal Zone Management
Tourism	1979	Environment and Tourism
Peri-Urban Areas	1979	Role of Agriculture in the Planning and Management of Peri-Urban Areas
Radioactive Waste	1977	Multilateral Consultation and Surveillance Mechanisms for Sea Dumping of Radioactive Waste
Multinational Enterprises	1984	Guidelines for Multinational Enterprises

OECD also has a major program examining the environmental implications of chemical use from early development through final disposal. Activities include information exchange, testing and assessment, international cooperation on chemicals management, accidents, and the assessment of impacts of chemical control policies, including the safety aspects of biotechnology materials. For example, OECD approved a system for testing chemicals before they enter the market and developed standards to permit tests in one member country to be accepted by others.

The Environment Committee also is involved in economic development, including agricultural policies, the use of economics in environmental policies, groundwater management, and the strengthening of economic relationships with developing countries. Some activities are conducted in conjunction with other committees, such as the OECD Development Assistance Committee. In the areas of prevention and control, activities include hazardous waste management, control of major air pollutants, cross-media approaches to pollution control, siting of hazardous installations, and noise abatement. OECD also conducts national reviews, provides periodic state of the environment reports, and conducts studies on urban environmental issues.

European Community

The economic and environmental agendas of western European trading partners have come together in the European Community (EC), also called the European Economic Community. EC is distinct from the U.N. Economic Commission for Europe (ECE). EC agendas are of particular interest to the United States, since they relate to environmental as well as trade policies.

What had begun as economic cooperation in the 1950s in several organizations designed to coordinate trade among the coal, steel, and atomic energy sectors in western Europe has evolved since the 1970s into an integrated organization dedicated to trade and environmental policy.[21] In 1967 several organizations merged into the EC, which is now comprised of Belgium,

Denmark, France, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, the United Kingdom, and the Federal Republic of Germany. Since its formation in 1972, the Directorate for Environment, Consumer Protection, and Nuclear Safety (DGIX) has played an increasingly important role in developing environmental policies for consideration by member nations. EC has established pollution controls for member countries despite the fact that the individual countries previously had been unable to do so.

EC can enact regulations that become binding on members, issue directives that members must implement domestically, as well as offer recommendations, resolutions, and opinions. The net effect of these actions is to require members to have in place or establish by domestic legislation environmental controls that meet common EC standards. A selected listing of EC directives is shown in Table 7-4.

As a representative of regional interests, EC has become a party to several international environmental protection agreements:

- The 1974 Paris Convention on the Prevention of Pollution from Land-Based Sources,
- The 1976 Bonn Convention on the Protection of the Rhine against Pollution by Chemicals,
- The 1976 Barcelona Convention on the Protection of the Mediterranean Against Pollution and its three related protocols,
- The 1979 Geneva ECE Convention on Long-Range Transboundary Air Pollution in Europe,
- The Vienna Convention on the Protection of the Ozone Layer and its 1987 Montreal Protocol, and
- The 1989 Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal.

Table 7-4.—Environmental Legislation and Policy Decisions Adopted by the European Community, 1970–86.

ACTION	DATE	SUBJECT	REFERENCE
Council Directive 70/157/EEC	6 February 1970	Permissible Sound Level and the Exhaust System of Motor Vehicles.	OJ L 42 (1970), page 16. Last Amended by Directive 84/424/EEC, OJ L 238 (1984), page 31.
Council Directive 70/220/EEC	20 March 1970	Air Pollution by Gases from Engines of Motor Vehicles.	OJ L 76 (1970), page 1. Last Amended by Directive 83/351/EEC, OJ L 197 (1983), page 1.
Agreement	5 March 1973	Information for the Commission and for the Member States with a View to Possible Harmonization throughout the Communities of Urgent Measures concerning the Protection of the Environment.	OJ C 9 (1973), page 1.
Declaration of the Council of the European Communities and of the Representatives of the Governments of the Member States, Meeting in the Council	22 November 1973	Program of Action of the European Communities on the Environment.	
Agreement	15 July 1974	Supplement to the Agreement of 5 March 1973.	OJ C 86 (1974), page 2.
Council Directive 75/440/EEC	16 June 1975	Quality Required of Surface Water Intended for the Abstraction of Drinking Water in the Member States.	OJ L 194 (1975), page 26.
Council Directive 75/439/EEC	16 June 1975	Disposal of Waste Oils.	OJ L 194 (1975), page 23.
Council Directive 75/442/EEC	15 July 1975	Waste.	OJ L 194 (1975), page 39.
Council Directive 75/716/EEC	24 November 1975	Approximation of the Laws of the Member States relating to the Sulphur Content of Certain Liquid Fuels.	OJ L 307 (1975), page 22.
Council Directive 76/160/EEC	8 December 1975	Quality of Bathing Water.	OJ L 31 (1976), page 1.
Council Directive 76/403/EEC	6 April 1976	Disposal of Polychlorinated Biphenyls and Polychlorinated Terphenyls.	OJ L 108 (1976), page 41.

Table 7-4.—Environmental Legislation and Policy Decisions Adopted by the European Community, 1970–86 (cont.).

ACTION	DATE	SUBJECT	REFERENCE
Council Directive 76/464/EEC	4 May 1976	Pollution Caused by Certain Dangerous Substances Discharged into the Aquatic Environment of the Community.	OJ L 129 (1976), page 23.
Council Directive 76/769/EEC	27 July 1976	Approximation of the Laws, Regulations, and Administrative Provisions of the Member States relating to Restrictions on the Marketing and Use of Certain Dangerous Substances and Preparations.	OJ L 262 (1976), page 201. Last Amended by Council Directive 85/610/EEC, 20 December 1985, OJ L 375 (1985), page 1.
Resolution of the Council of the European Communities and of the Representatives of the Governments of the Member States, Meeting within the Council	17 May 1977	Continuation and Implementation of a European Community Policy and Action Program on the Environment.	OJ C 139 (1977), page 1.
Council Directive 78/176/EEC	20 February 1978	Waste from the Titanium Dioxide Industry.	OJ L 54 (1978), page 19.
Council Directive 78/319/EEC	20 March 1978	Toxic and Dangerous Waste.	OJ L 84 (1978), page 43.
Council Directive 79/409/EEC	2 April 1979	Conservation of Wild Birds.	OJ L 103 (1979), page 1.
Council Directive 79/831/EEC	18 September 1979	Amending for the Sixth Time Directive 67/548/EEC on the Classification, Packaging, and Labeling of Dangerous Substances.	OJ L 259 (1979), page 10.
Council Directive 80/68/EEC	17 December 1979	Protection of Groundwater against Pollution Caused by Certain Dangerous Substances.	OJ L 20 (1980), page 43.
Council Directive 80/51/EEC	20 December 1979	Limitation of Noise Emissions from Subsonic Aircraft.	OJ L 18 (1980), page 26.
Council Directive 80/779/EEC	15 July 1980	Air Quality Limit Values and Guide Value for Sulphur Dioxide and Suspended Particulates.	OJ L 229 (1980), page 30.
Council Directive 80/778/EEC	15 July 1980	Quality of Water Intended for Human Consumption.	OJ L 229 (1980), page 11.
Council Directive 82/176/EEC	22 March 1982	Limit Values and Quality Objectives for Mercury Discharges by the Chlor-Alkali Electrolysis Industry.	OJ L 81 (1982), page 29.

Council Directive 82/501/EEC	24 June 1982	Major-Accident Hazards of Certain Industrial Activities.	OJ L 230 (1982), page 1.
Council Directive 82/884/EEC	3 December 1982	A Limit Value for Lead in the Air.	OJ L 378 (1982), page 15.
Council Regulation (EEC) NO 2626/82	3 December 1982	Implementation in the Community of the Convention of International Trade in Endangered Species of Wild Fauna and Flora.	OJ L 384 (1982), page 1.
Resolution of the Council of the European Communities and of the Representatives of the Governments of the Member States, Meeting within the Council	7 February 1983	Continuation and Implementation of a European Community Policy and Action Program on the Environment (1982–86).	OJ C 46 (1983), page 1.
Council Directive 83/513/EEC	26 September 1983	Limit Values and Quality Objectives for Cadmium Discharges.	OJ L 291 (1983), page 1.
Council Directive 84/156/EEC	8 March 1984	Limit Values and Quality Objectives for Mercury Discharges by Sectors Other than the Chlor-Alkali Electrolysis Industry.	OJ L 74 (1984), page 49.
Council Regulation (EEC) No 1872/84	28 June 1984	Action by the Community relating to the Environment.	OJ L 176 (1984), page 1.
Council Directive 84/360/EEC	28 June 1984	Combating of Air Pollution from Industrial Plants.	OJ L 188 (1984), page 20.
Council Directive 84/538/EEC	17 September 1984	Permissible Sound Power Level of Lawnmowers.	OJ L 300 (1984), page 171.
Council Directive 84/491/EEC	9 October 1984	Limit Values and Quality Objectives for Discharges of Hexachlorocyclohexane.	OJ L 274 (1984), page 11.
Council Directive 84/631/EEC	6 December 1984	Supervision and Control within the European Community of the Transfrontier Shipment of Hazardous Waste.	OJ L 326 (1984), page 31.
Council Directive 85/203/EEC	7 March 1985	Air Quality Standards for Nitrogen Dioxide.	OJ L 87 (1985), page 1.
Council Directive 85/210/EEC	20 March 1985	Approximation of the Laws of Member States concerning the Lead Content of Petrol.	OJ L 96 (1985), page 25.

Table 7-4.—Environmental Legislation and Policy Decisions Adopted by the European Community, 1970–86 (cont.).

ACTION	DATE	SUBJECT	REFERENCE
Council Decision 85/338/EEC	27 June 1985	Adoption of the Commission Work Program Concerning an Experimental Project for Gathering, Coordinating and Ensuring the Consistency of Information on the State of the Environment and Natural Resources in the Community.	OJ L 176 (1985), page 14.
Council Directive 85/337/EEC	27 June 1985	Assessment of the Effects of Certain Public and Private Projects on the Environment.	OJ L 175 (1985), page 40.
Council Directive 85/339/EEC	27 June 1985	Containers of Liquids for Human Consumption.	OJ L 176 (1985), page 18.
Council Resolution	6 March 1986	Action Program for the European Year of the Environment (1987).	OJ C 63 (1986), page 1.
Council Directive 86/280/EEC	12 June 1986	Limit Values and Quality Objectives for Discharges of Certain Dangerous Substances Included in List 1 of the Annex to Directive 76/464/EEC.	OJ L 181 (1986), page 16.
Council Directive 86/278/EEC	12 June 1986	Protection of the Environment, and in particular, of the Soil when Sewage Sludge Is Used in Agriculture.	OJ L 181 (1986), page 6.

EC also has established a series of comprehensive environmental programs. The first Community Action Program, begun in 1973, was concerned primarily with immediate responses to the serious problems posed by air and water pollution, noise, and waste. The 1977 Community Action Program emphasized the prevention of environmental deterioration and the rational management and conservation of resources and space. The third action program, adopted in 1983, called for continuation and completion of those projects initiated in the first and second programs, and it represented an overall preventive strategy for safeguarding the environment and natural resources. A key legislative measure in this preventative approach was the EC directive, adopted in 1985, under which the construction of major industrial and infrastructural developments became subject to an environmental impact assessment requirement.

EC broadened its preventative strategy and made environmental protection an essential element of all economic and social policies in its fourth action program, scheduled to run from 1987 to 1992, and it is in process of establishing a European Environmental Agency. That program entails actions in the following areas:

- **More effective integration of environmental policy into all EC policies, including agriculture, industry, competition, energy, internal market transport, tourism, social policy, and regional policy.** For example, before investment aid is provided by EC, greater attention must be paid to environmental considerations. Common agricultural policy also has to ensure a fair balance between agricultural production and the sometimes conflicting need to safeguard the environment.

- **Stricter environmental standards set in the context of completion of EC internal markets.** In addition to environmental benefits, EC believes that most successful manufacturers will be those that can best adapt to growing demand, in Europe and worldwide, for higher environmental standards and nonpolluting products. Strict standards are therefore necessary for economic reasons, because they will make EC industry more competitive.

■ **Promotion of investment to improve the environment.** Through the European Investment Bank and other economic assistance organizations, EC has supported environmental improvement projects such as water purification plants and sanitation systems.

■ **Improved public access to EC information.** EC sponsors various information dissemination programs so that citizens may better know and defend their rights and interests.

■ **Effective implementation of EC legislation that protects the environment.** EC works to ensure that member states properly translate EC directives into their national legislation and apply them.

■ **Efforts to prevent and control pollution.**[22]

International Agreements

In 1989 an array of international agreements governed pollution control, use of natural resources, preservation of species, and other aspects of the environment. The United States has been and continues to be an active participant in treaty negotiations and implementation, often taking a leading role. To date, the United States has ratified more than 40 binding instruments in the field of the environment and also participates in many nonbinding environmental preservation regimes. Under these agreements, nations give up a degree of sovereignty to achieve mutually beneficial objectives. Agreements included the following:

- Statements of common concerns,
- Definitions,
- Some type of control regime,

- Requirements for information sharing,
- Funding mechanisms and frameworks for conducting research,
- Establishment of a secretariat to administer the agreement, and
- A requirement for periodic meetings of the parties to update terms of the agreement.

While the effectiveness of a particular agreement can be difficult to measure, the fact that governments have agreed to cooperate in so many ways suggests that international efforts to protect the environment have evolved substantially since 1970.

The extent of formal intergovernmental arrangements is illustrated by the list of 140 international treaties and other agreements in the field of the environment compiled in May 1989 by UNEP and included as Appendix C to this report. Almost two-thirds of these agreements were signed after 1970. In addition, many other regional and bilateral agreements have addressed environmental issues indirectly. Taken together, all these international agreements today help manage environmental problems that cross national borders.

Multilateral Agreements

Since the early 1970s, agreements signed by a number of nations have addressed species protection, ocean pollution, atmospheric pollution, and hazardous wastes, among other topics.

Species and Habitats

Biodiversity refers to the variety and variability among living organisms and the ecological complexes in which they occur. The loss of biodiversity is a serious environmental—and economic—concern. Human prosperity is based very largely on the ability to use biological diversity; that is, to take advantage of the properties of plants, animals, fungi, and microorganisms for food, cloth-

ing, medicine, and shelter. In the words of the National Science Foundation:

> *The extinction event that we are witnessing is the most catastrophic loss of species in the last 65 years. Most importantly, it is the first extinction event that has been caused by a single species, one that we hope will act in its own self interest to stem the tide.*
>
> *Unless the international community can, indeed, reverse the trend, the rate of extinction over the next few decades is likely to rise to at least 1000 times the normal background rate of extinction, and will ultimately result in a loss of a quarter or more of the species on earth.*[23]

Over the past 20 years, several international agreements among governments have attempted to preserve species and habitats. In addition, other types of international action can help preserve species. Examples are intergovernmental agreements for fish conservation through groups like the Inter-American Tropical Tuna Commission, and the development of international seed banks through the Food and Agriculture Organization (FAO) of the United Nations. The UNEP Regional Sea Program also developed a number of protocols on special protected areas and wildlife under regional conventions.

A growing loss of habitat for migratory birds led to the Convention on Wetlands of International Importance with the focus on waterfowl habitat. Concluded in Ramsar, Iran, in 1971, the convention required international designation of wetlands and imposed an obligation to consider the preservation and conservation of all wetlands having international importance in terms of waterfowl habitat, marine productivity, or flood control.

The 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) controls or curbs trade in threatened and endangered species. It has achieved success, for example, with the American alligator and certain spotted cats.

In 1989 it was used to curtail international traffic in ivory. CITES was the end result of efforts begun a decade earlier by the International Union for the Conservation of Nature and Natural Resources that were supported in the United States by the 1969

passage of the Endangered Species Conservation Act.[24] Membership in the convention is open to all nations, whether producers or consumers of wildlife, that wish to reduce the impact of international trade on endangered species. CITES protects over 500 species of animals and over 20,000 species of plants.[25] It prohibits or very strictly limits trade in those endangered species listed in Appendix I to the treaty, and regulates those plants and animals that are in less immediate danger but are still threatened. The Convention on the Conservation of Migratory Species of Wild Animals was concluded in Bonn in June 1979. It provides a broad framework for conservation of all migratory species, with emphasis on those in need of particular protection. This umbrella agreement is designed to encourage nations to negotiate regional or bilateral agreements on species protection. Sixty-three nations participated in the Bonn conference, but the United States did not sign because of the ambiguous definition of migratory species in the convention. In October 1988 the definition was tightened to correct the ambiguity.

The 1980 Convention on the Conservation of Antarctic Marine Living Resources was designed to safeguard the Antarctic environment, protect the integrity of the seas surrounding Antarctica, and preserve its marine resources. The Convention is an outgrowth of the Antarctic Treaty of 1959 that reserves Antarctica exclusively for peaceful purposes and establishes a basis for international scientific cooperation. It reflects an ecosystem-wide approach to management of shared resources and supplements earlier conservation agreements. In 1988 the Antarctic Treaty Parties finished negotiating the Convention on the Regulation of Antarctic Mineral Resource Activities, which establishes a regulatory framework for the consideration of proposed prospecting, exploration, and development of antarctic oil and mineral resources. The Minerals Convention, which is not yet in force, prohibits exploration and development until institutions established under the Convention agree that substantive environmental and information standards are met.

International efforts to protect whales reached fruition in 1982 with an agreement by the International Whaling Commission to ban all commercial whaling; that agreement became effective after 1985, although the harvesting of certain species had been limited prior to that time. It is noteworthy that internation-

al initiatives to ban whaling began as far back as the League of Nations Convention for the Regulation of Whaling in 1931, and in 1946 the International Whaling Commission (IWC) was established.

The 1973 Agreement on the Conservation of Polar Bears[26] addresses concerns about the decline of the polar bear as a result of hunting. The United States, Soviet Union, Canada, Denmark, and Norway Islands are parties to this agreement for cooperation in research on polar bear biology and controls on the taking of bears. Other efforts include the International Union for the Conservation of Nature and Natural Resources draft for a possible biodiversity convention, the UNEP mandate to protect biological diversity, and the U.N. Food and Agriculture Organization program for biodiversity.

Oceans

The oceans make up two-thirds of the surface area of the planet. From time to time, major pollution incidents, such as *Torrey Canyon* (1967), *Amoco Cadiz* (1978), and *Exxon Valdez* (1989), have focused the attention of the world on the oceans and the need to establish effective international measures to protect the marine environment.

Following the *Torrey Canyon* spill off the coast of England, the International Maritime Consultative Organization (IMCO)—now the International Maritime Organization (IMO)—convened a conference to address the question of shipowner liability for oil pollution damage and the right of governments to intervene on the high seas when ship casualties threaten to pollute the coasts of their States with oil. The conference, held in 1969, adopted two conventions for these purposes, the Convention on Civil Liability for Oil Pollution Damage and the Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties. The conference also recognized the need to supplement the shipowner's liability with an international fund, and called for IMCO to convene a conference to develop such a scheme. In 1971 IMCO convened such a conference, which adopted the Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage.

IMCO recognized the need to improve the international regulatory regime to prevent pollution from ships. It convened a Conference in 1973 for that purpose and to extend the application of the 1969 Intervention Convention to substances other than oil. The conference adopted the Convention for the Prevention of Pollution from Ships (MARPOL) and the Protocol Relating to

Intervention on the High Seas in Cases of Marine Pollution by Substances Other than Oil. MARPOL contains five annexes, each directed at a different ship source pollution problem:

- Annex I, pollution by oil;
- Annex II, pollution by noxious liquid substances in bulk;
- Annex III, pollution by packaged harmful substances;
- Annex IV, pollution by sewage; and
- Annex V, pollution by ship garbage.

The requirements of Annex I were strengthened at the Tanker Safety and Pollution Prevention Conference convened by IMCO in 1978. That conference adopted amendments to the MARPOL Annex through the Protocol Relating to the International Convention for the Prevention of Pollution from Ships (as so amended, the acronym is MARPOL 73/78) and supplemented those amendments through the Protocol Relating to the Convention on the Safety of Life at Sea.

Annexes I and II entered into force with MARPOL 73/78. Annexes III and IV have yet to enter into force. However, Annex V entered into force in 1988. Among other things, Annex V prohibits absolutely the disposal at sea of all plastics; it is considered to be an important contribution to international efforts to deal with the problem of marine debris.

Largely due to U.S. efforts and the devastation following the *Amoco Cadiz* spill off the coast of France, IMO convened a conference in 1984 to revise the 1969 Civil Liability Convention and the 1971 Fund Convention. That conference adopted the Protocol of 1984 to amend the International Convention on Civil Liability for Oil Pollution Damage, 1969, and the Protocol of an International Fund for Compensation for Oil Pollution Damage, 1971. Those Protocols substantially raise the compensation available to

governments and other victims of tanker source oil pollution (up to approximately $260 million). They are currently before the U.S. Senate for advice and consent, and implementing legislation is being considered by the Congress.

Ocean dumping of wastes was the subject of two treaties in the early 1970s. Under the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters (London Convention of 1972), nations agreed to regulate all ocean dumping through national authorities. No dumping is allowed without a permit, dumping of hazardous substances is allowed only pursuant to a special permit issued by the national authority, and other materials may be dumped only pursuant to a general permit. Before issuing a permit, national authorities must consider various environmental criteria listed in an annex to the convention. Certain wastes are prohibited from sea disposal, such as high level radioactive wastes.

Whereas the London Convention may be generally applicable to high seas, the Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (Oslo Convention of 1972) pertains to the Northeast Atlantic. Both treaties contain annexes that specify in detail the items regulated, and the Oslo Convention establishes a group to assess the effectiveness of measures taken. By providing a more precise meaning to each country's reasonable regard for use of the ocean, these conventions are "steps toward responsible management of the international commons of the oceans."[27]

Land-based sources of marine pollution, which are increasingly recognized as a threat to coastal waters, have been addressed at the regional level through agreements such as the 1974 Paris Convention on the Prevention of Marine Pollution from Land-Based Sources, the 1974 Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area, and several U.N. Regional Seas agreements.

Rules related to the sharing of ocean resources have grown from a series of U.N.-sponsored meetings that began in 1970 when the U.N. General Assembly called for a Law of the Sea Conference to stabilize international rules governing national rights in the oceans and, particularly, to establish a set of rules for mineral exploration and exploitation of the seabeds. The conference also was to consider issues concerning the high seas, the

continental shelf, the territorial sea, and contiguous zones. The zones include international straits, fishing and conservation of the living resources of the high seas, the preservation of the marine environment, and scientific research.[28]

The Law of the Sea Conference began with an organizational session in New York in October 1973, and it concluded with a final session in New York in 1982. Although the conference resulted in a convention that manifested substantial international agreement on uses of oceans, including protection of the ocean environment, the United States did not sign it because of problems with the deep seabed mining provisions. The convention has yet to be brought into effect. However, the United States does accept and act in accordance with substantive provisions relating to matters such as navigation, obligations to prevent marine pollution including pollution from vessels, continental shelf activities, and waste disposal at sea. In general, the United States regards the convention's provisions on protection of the marine environment as reflective of customary international law.

Regional arrangements to protect the oceans have emerged out of the U.N. Regional Seas Program, a program that has promoted the protection and management of the marine environments and coastal areas of particular water basins. The program is premised upon the assumption that countries in a particular region share a common interest in safeguarding their marine environment and have mutual need for sustainable development of marine resources. It states:

> *Coastal waters, estuaries, and enclosed and semi-enclosed seas suffer the earliest and most severe degradation from the effects of urbanization, industrialization, agriculture, transportation, and other human activities, while concurrently containing ecosystems which are among the highest in biological productivity (90 percent of the marine catch coming from such areas). These waters are therefore logical starting points for combating marine pollution. The regional approach allows specific priorities, needs, and capabilities to be taken into account in the formulation of action plans designed to cope with the environmental problems of the oceans as a whole.*[29]

Regional sea agreements are in effect for 10 areas: the Mediterranean Sea, the Red Sea and Gulf of Aden, the Kuwait region of the Persian Gulf, the West and Central African regions, the East Asian seas, the Southeast Pacific, the South Pacific, the Eastern African region, the Southwest Atlantic, and the wider Caribbean region. For example, in 1983 the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region was signed at Cartagena, Colombia. A Convention for the Protection of the Natural Resources and Environment of the South Pacific Region was agreed to in Noumea, New Caledonia, in 1986, but it is not yet in force.

Atmosphere

The atmosphere is a resource shared by all nations, although certain atmospheric conditions are regional and particular effects may be unevenly distributed. For example, acid rain was one of the major concerns that led to the 1979 ECE Convention on Long-Range Transboundary Air Pollution (LRTAP) and a subsequent protocol for cooperative monitoring and evaluation. Controls on certain acidic air pollutants were developed by the Economic Commission for Europe. Ongoing activities under LRTAP include studying the effects of sulfur compounds on the environment, assessing control technologies, monitoring and evaluating the long-range transmission of air pollutants, and reviewing strategies and policies for the abatement of air pollution caused by sulfur compounds.

A 1985 protocol commits countries to reduce sulfur dioxide emissions or transboundary fluxes by 30 percent. Because of substantial success in the United States in reducing sulfur emissions prior to 1980 and because the United States would not receive credit for prior actions, the United States did not sign this protocol. However, the United States did sign the 1988 ECE protocol on nitrogen oxides or their transboundary fluxes, and was one of the first countries to submit its instrument of acceptance. The main provisions of the 1988 protocol include:

- A freeze on nitrogen oxide emissions at 1987 levels by December 31, 1994;
- The use of best available technologies on new sources, when economically feasible;

- A commitment to develop a follow-on protocol to meet environmental effects control standards, instead of emissions control standards as in the present protocol, for implementation in 1996;
- The exchange of information on control technologies; and
- Increased availability of unleaded gasoline in Europe. The parties to LRTAP have also established working groups on abatement strategies.

Increases in certain atmospheric pollutants have led to concerns about depletion of the ozone layer and potential rise in global temperatures. The stratospheric ozone layer, which protects the earth from dangerous ultraviolet radiation, is being damaged by complex chemical reactions stemming from the release of chlorofluorocarbons.

The 1985 Vienna Convention for the Protection of the Ozone Layer completed events begun a decade earlier. In 1976 the UNEP Governing Council called for a meeting to coordinate activities on protecting the ozone layer. The following year, the United States hosted a UNEP experts meeting—the World Conference on the Ozone Layer—that recommended a plan of action and established a Coordinating Committee on Ozone Layer to conduct an annual review of the science. The work of the committee helped develop the eventual international agreement at Vienna.

In Oslo in April 1980, representatives from the United States, Canada, Denmark, the Federal Republic of Germany, the Netherlands, Norway, Sweden, and the European Community acknowledged an urgent need to reduce worldwide CFC emissions and suggested negotiating an international convention. In May 1981 the UNEP Governing Council established a working group to negotiate a convention for the protection of the ozone layer. Negotiations began in January 1982, and by December drafting of the convention had begun. The Convention for the Protection of the Ozone Layer was adopted in March 1985.

The Vienna Convention was a "framework convention" in that it provided a structure by which the parties could agree on

specific protocols to control economic activities that caused adverse effects on the ozone layer; to cooperate on research, legal, scientific, and technical issues; and to convene regular meetings to refine the convention. The convention included two annexes, one related to research and the other to information exchange.

The convention did not specify actions to reduce the global use of specific chemicals or products. Rather, it provided for the negotiation and possible adoption of protocols that could coordinate regulatory measures considered necessary for the protection of the ozone layer. Efforts to agree on a protocol did not succeed, in part because of different views on the science of ozone layer depletion, its environmental implications, and the socioeconomic implications of various control strategies. Instead, the conference adopted a resolution calling for interim CFC controls and a socioeconomic, scientific, and technical workshop to help build a consensus and agree on a date certain to commence negotiations.

The Montreal Protocol on Substances that Deplete the Ozone Layer was adopted as a protocol to the Vienna Convention in 1987. The Montreal Protocol calls for a freeze in CFC consumption at 1986 levels, beginning 90 days after the protocol entered into force, which was January 1, 1989. Reductions of 20 percent from 1986 levels are required by July 1, 1993, with reductions of 50 percent by July 1, 1998. Halon consumption is frozen at 1986 levels in 1992. The protocol also prohibits trade in controlled substances between parties and nonparties; phases in a ban on imports of products containing controlled substances; prohibits parties from providing nonparties with financial assistance to produce controlled substances; and allows developing countries that are parties to increase their consumption of controlled substances for up to 10 years to meet basic domestic needs, provided they do not exceed 0.3 kg per capita annual consumption.

The protocol is not static. Because of many scientific uncertainties, it calls for reassessments of provisions on a regular basis. The first of these reassessments will occur in 1990 based on studies conducted during 1989. Should new data warrant it, adjustments may be made to the amount and timing of the reductions mandated by the protocol, and other chemicals may be controlled.

The value of regularly scheduled reassessments of the Montreal Protocol can be seen from the first meeting of the Parties to the Montreal Protocol held in May 1989 in Helsinki. In the period between the signing of the protocol and this Meeting of the Parties, accumulated scientific evidence indicated that a 50-percent reduction in CFC consumption would not be sufficient to protect the ozone layer and that further reductions were needed. Therefore, delegates to the Helsinki meeting called for the elimination of CFCs by the year 2000, provided safe substitutes were available. The delegates also established working groups to develop proposals for strengthening the protocol and recommendations on financial and other mechanisms to assist developing countries in implementing it.

The working groups held their first meeting in Nairobi in August 1989, the second in November 1989, and the third in February 1990. They will make recommendations to the protocol parties at the second Meeting of the Parties in June 1990 in London. At the August meeting, the Working Group on Financial Assistance recommended a series of country-specific studies to determine overall needs of developing countries. It also called for a study of the potential role of both new and existing funding institutions or mechanisms to assist in the transfer of needed technology to developing countries.

Hazardous Wastes

The 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal arose from UNEP-sponsored negotiations. It drew extensively on OECD work and supports ongoing OECD activity. Fundamental elements of the convention are notice and consent requirements. This convention recognizes the problems associated with hazardous wastes and takes the most significant step toward international control of waste movement that has occurred since the 1970s.

The transboundary movements of hazardous wastes can pose significant threats to health and the environment, if receiving countries lack the capacity to manage or dispose of wastes in an environmentally sound manner. Thus parties to the Basel Convention must require that wastes to be exported are managed in

an environmentally sound manner. Exports of hazardous wastes are prohibited, despite an importing party's consent, if there is reason to believe environmentally sound management will not occur. Banned are exports to and imports from nonparties, unless pursuant to a bilateral agreement that comports with the convention. Convention controls also extend to wastes not designated as hazardous, such as incinerator ash and household garbage. It also prohibits any shipment of hazardous waste to Antarctica. The United States signed the Basel Convention in March 1990.

World Heritage

A World Heritage Trust was formally proposed by President Richard Nixon in 1971 and has since been agreed to by over 100 nations. In response, at its fall 1972 meeting in Paris, the General Conference of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) adopted the convention on the Protection of the World Cultural and Natural Heritage. This treaty for preservation and restoration of the outstanding cultural and natural areas of the world relies on a list established by the World Heritage Committee and World Heritage Fund. Despite relatively limited finances, the convention has served as a catalyst for preservation of areas whose loss would be irreparable.

Environmental Modifications

In the early 1970s the ability of modern science to modify weather led to increased concerns that such modifications be conducted solely for peaceful purposes. The dangers of environmental modification for military purposes were especially disturbing. The Convention on the Prohibition of Military or any other Hostile Use of Environmental Modification Techniques was adopted in New York in 1976. Parties agree not to use environmental modification techniques having widespread, long-lasting, or severe effects as the means of destruction, damage, or injury to other parties, or to assist another state to do so.

North American Regional Arrangements

In 1920 international environmental issues affecting the North American continent were largely related to U.S. boundary waters with Canada and Mexico. At different times the quantity of available water and the quality of that water caused international concerns. Distributing the available water flow between the neighboring countries has required continuous attention since the early years of this century.

In the 1970s several kinds of pollution issues were added to the agenda. The threat to the Great Lakes was one of the first major transboundary environmental crises to attract widespread public attention. In 1972 the Great Lakes Water Quality Agreement was concluded with Canada; it has been amended twice to focus on new issues like toxics and to enlarge its scope to the entire ecosystem. As a result, the immediate threat of eutrophication was avoided, but not toxic contamination. (See Chapter 8 of this report for a more detailed discussion of the Great Lakes.)

During the 1970s Mexico and the United States became concerned about the quantity of water being apportioned from the Colorado and Rio Grande Rivers. The subsequent increase in surface water salinity led ultimately to an agreement to build a large desalinization facility on the U.S.-Mexican border.

In the early 1980s U.S. and Mexican concerns over border issues led Presidents Reagan and De La Madrid to sign an Agreement for Cooperation on Environmental Programs and Transboundary Problems. It provides a broad framework to address common border environmental problems such as copper smelters, urban air quality, and spills of hazardous materials. This cooperation has been extended to efforts to protect Mexico City's environment under an agreement signed in October 3, 1989, at the U.S.-Mexican Summit.

A number of other issues with more localized impacts have occupied the attention of the United States and its neighbors, for example the Garrison Diversion on the Canadian border and pollution of the Tijuana River on the Mexican border. As authorized by the U.S. Congress in 1965, the Garrison Diversion would have diverted water from the Missouri River through a large irrigation development into the Hudson Bay Drainage Basin. The Interna-

tional Joint Commission called the dispute over this project "one of the most difficult and intricate issues the Commission has ever been asked to consider."[30] Canada argued that the project would transfer biota, such as fish, fish eggs, and parasites, fish diseases, and nitrogen into Canadian waters. Only a portion of the original plan has been executed.

Through the Tijuana River, the United States receives pollution from the Mexican border city of Tijuana, which has limited sewage and wastewater treatment. The issue has been discussed repeatedly between the two countries in the International Boundary Waters Commission. One treatment plant was built in 1962; a second one, funded in 1987, will lead to improvements. In 1980 as part of the IXTOC offshore drilling incident, the United States and Mexico signed an agreement on marine pollution contingency planning to deal with spills of oil and other hazardous substances at sea.

In 1986 United States and Canada signed an agreement, known as the North American Waterfowl Management Plan, to restore the continent's waterfowl populations to the numbers that had occurred in the early 1970s. In December 1989 President Bush signed the North American Wetlands Protection Act, which authorized funding to implement the objectives of the plan. Administered from the United States by the DOI/Fish and Wildlife Service, the plan uses the concept of "joint ventures"—cooperative efforts with states, business, and industry, conservation organizations, and private landowners in both counties—to protect and restore wetland habitats. The plan has targeted more than 5 million acres of key waterfowl habitat for protection through designation of critical areas, providing incentives to private landowners for restoration of wetlands, and improving habitat on existing wildlife refuges, military lands, and other public lands.

Over the past 20 years, Canada and the United States have become increasingly concerned over the environmental—and diplomatic—fallout from acid rain. Despite U.S. measures to reduce acidifying emissions through the Clean Air Act Amendments of 1977, Canada continued to object to acidic air pollutants that were emitted in the United States and deposited in Canada. There, acidifying pollutants were believed to exceed the absorptive capacity of Canadian lakes and forests, which generally are more susceptible to acidification than many of those in the

United States. The two countries disagreed over the extent and likely future impacts of acid rain.

In 1979 the two countries signed a Memorandum of Intent to set up a cooperative scientific process that was to lay the groundwork for a future agreement on controls. Then in 1980 the U.S. Congress passed legislation establishing a 10-year acid rain research program. That program, which has invested about $500 million in acid rain studies over the past decade, is now drawing to a close, and President Bush has announced proposed amendments to the Clean Air Act that, among other things, would cut acidic air pollutants by nearly half. In late 1989 discussions were initiated between the two countries to conclude an air quality accord.

Other Bilateral Agreements

Besides its cooperative activities with its North American neighbors, the United States has entered into a range of international agreements outside this continent regarding environment-related matters. The agreements include formal arrangements with other governments and less-formal activities with both multinational and nongovernmental organizations

Before 1970 the United States had entered into few environmental bilateral agreements with countries outside of North America. However, beginning in the early 1970s, international cooperative efforts began to grow. President Nixon and President Podgorny of the Soviet Union signed a historic environmental agreement on May 23, 1972. That agreement extends cooperative U.S.-Soviet activities in 11 problem areas, including air and water pollution, the urban environment, the influence of environmental change on climate, earthquake prediction, arctic and subarctic ecological systems, and legal and adminstrative measures. Over the years, the number of cooperative projects has grown significantly, and the agreement has ongoing importance to bilateral environmental protection efforts.

The significance of U.S.-Soviet bilateral cooperation was dramatized by several catastrophic events during the past few years. After the Armenian earthquake of December 1988 and the

Loma Prieta earthquake of October 1989, joint U.S.-Soviet research teams were dispatched to the disaster sites. And in the days following the March 1989 *Exxon Valdez* oil spill, U.S.-Soviet bilateral contacts helped facilitate Exxon's use of a Soviet oil-skimming vessel. At the January 1990 meeting of the U.S.-Soviet Joint Committee, which oversees the bilateral agreement, the number of separate major topic areas grew to 12, with a total of over 45 specific projects. The participants also examined the possibility of significantly increasing the amount and level of participation by both U.S. and Soviet nongovernmental organizations.

Other agreements were concluded in the early 1970s with the European Community, Spain, the Federal Republic of Germany, Japan, several Eastern European countries, India, Pakistan, Tunisia, and Egypt. Agreements were signed with Panama and several South American governments as well. Ministerial conferences were held with Japan as early as 1970, 1971, and 1973 to focus on environmental issues such as solid waste management, marine resources, forestry, and national parks.

U.S. federal agencies support a number of environmental bilateral agreements. Because the environment touches many aspects of international relations, and because the international responsibilities of the agencies are so diverse, it would be difficult to describe fully the complete range of their environmental bilateral activities. Moreover, many international programs established for other purposes could be viewed as environment-related.

Federal agencies such as the National Science Foundation (NSF), the Environmental Protection Agency (EPA), the U.S. Agency for International Development (USAID), the Peace Corps, and the Departments of Commerce, Energy, Agriculture, Interior, and Health and Human Services are engaged in bilateral environmental activities. Such activities include the development of pollution cleanup and prevention technology, scientific training, public health assistance, economic aid, and the exchange of information on environmentally sound energy technologies.

The number and kinds of international environmental activities continue to grow, stimulated most recently by the sweeping political changes in Eastern Europe. In 1989 President Bush visited Poland and Hungary and proposed expanded bilateral as-

sistance, subsequently embodied in Public Law 101-179, the Support for East European Democracy (SEED) Act of 1989. Among the proposed initiatives were three for Poland to assist in retrofitting an existing coal-fired plant, establishing an air quality monitoring network, and improving water quality and availability in Krakow. For Hungary, the President proposed a private regional environmental center in Budapest, funded by public and private funds, that would develop a broad human resource base for comprehensive environmental improvement and protection activities in the region.

Table 7-5 lists the current bilateral agreements that EPA has entered into since 1970, either individually or as the lead agency for the United States. The table does not include arrangements with multilateral organizations such as the European Community. These two dozen agreements, representing a range of environmental assistance activities, exemplify how much environmental interactions by the federal government with foreign governments have increased over the past 20 years.

Economic Summit, Paris, 1989: A Case Study of International and Domestic Action

The annual economic summit of seven industrialized nations, known as the "G-7," includes the leaders of Canada, the Federal Republic of Germany, France, Italy, Japan, the United Kingdom, and the United States, with participation by the European Community. Summits in the 1980s began to give attention to environmental issues.[31] The July 1989 Paris "Summit of the Arch" highlighted international environmental concerns about atmospheric pollution and climate change, the status and management of the earth's forests and oceans, and interrelated technological and economic issues. In fact, environmental issues constituted fully one-third of the Paris Summit Declaration.

Table 7-5.—U.S. Environmental Protection Agency Bilateral Agreements, 1972–89.

COUNTRY	DATE	PROJECT TYPE
Argentina	1989	Ozone in upper atmosphere study.
Brazil	1986	Agreement to provide technical assistance to CETESB, Sao Paulo state pollution control agency; formal agreement pending.
Canada	1978	US-Canadian governmental agreement for restoration and maintenance of the chemical, physical, and biological integrity of the waters of the Great Lakes Basin ecosystem.
	1985	A MOU outlines a plan of cooperative measures for dealing with accidental releases of pollutants which cause, or may cause, damage along the border, and constitute a threat to public health, property or welfare; a Joint Contingency Plan is being developed.
		Activities include pollution measurement and control, research and development and improved technologies and systems for pollution control.
	1986	A MOU provides for export, import, and transit of hazardous wastes across the boundary for treatment, storage, or disposal.
China	1980	US-PRC Protocol on Environmental Cooperation (5-year renewals) involves five ongoing projects under two annexes on aquatic effects of environmental pollution; health research (lung cancer; modeling of air pollution transport and transformation; water pollution transport; and pollution of soil and groundwater. A sixth project, environmental management, under the newly signed 4th Annex, is in planning.
Germany	1974	Governmental agreement, five-year automatic renewal, with EPA and Ministry of Environment, Nature Protection, and Reactor Safety as the lead agencies; broad range of cooperation on auto emissions, acid deposition, economic incentives, improved regulatory approaches, hazardous waste management and enforcement, chemical substances, pesticides, radiation, water pollution control, technologies for control of air pollution from stationary sources, protection of drinking water, and soil pollution.
India	1986	EPA works with environmental authorities of the Indian Government under the US-India Fund; principal project is the Ganges River cleanup; two joint toxicology research projects are being formulated. EPA is reviewing two project proposals by NEERI.
Italy	1987	At Italian request, EPA concluded a formal MOU with the newly established Ministry of Environment; subsequent governmental reorganization has precluded implementation; ongoing contacts exist in the fields of dioxin control, wastewater management, and solid waste management, and recycling.
Japan	1975	Self-renewing governmental agreement on environmental protection; 15 projects cover a range of issues including mobile and stationary source control, hazardous waste management, wastewater treatment, drinking water protection, and management of contaminated bottom sediments.
Korea	1987	A MOU between EPA and Korea Environment Agency was signed November 2, 1987 but does not enter into force until the umbrella US-ROK Science and Technology agreement is signed. Seven subjects for exchange were discussed at the 1987 meeting but none are underway.

Table 7-5.—U.S. Environmental Protection Agency Bilateral Agreements, 1972–89 (cont.).

COUNTRY	DATE	PROJECT TYPE
Mexico	1988	US-Mexican governmental agreement for cooperation in the protection, improvement, and conservation of the border environment; specific programs are outlined in annexes to the agreement: 1. Solution of the border sanitation problem at San Diego and Tijuana; 2. Cooperation on discharges of hazardous wastes along the border; 3. Cooperation on transboundary shipment of hazardous substances; 4. Cooperation on transboundary air pollution from copper smelters; 5. Cooperation on urban air quality.
	1989	US-Mexican governmental agreement on cooperation in protecting Mexico City's environment.
Netherlands	1985	Self-renewing MOU between EPA and the Ministry of Housing, Physical Planning, and Environment. Covers the same range of topics as the US-FRG agreement. EPA and the Ministry cosponsored a major international symposium on ozone, the third in a series of triennial symposia on major air-related issues.
Nigeria	1980	A MOU between EPA and Ministry of Housing for general environmental cooperation.
Poland	1987	Agreement between EPA and the Ministry of Environment which may cover air and water pollution, hazardous waste management, effects of pollutants on flora and fauna, radiation, health effects of pollutants, and environmental management and planning. EPA also participates in the US-Poland agreement on Science and Technology Cooperation, and is developing projects on health effects, radiation, and hazardous waste management.
USSR	1972	CEQ and the GOSKOMGIDROMET and now EPA and GOSKOMPRIRODA are lead agencies for this self-renewing governmental agreement; projects cover the areas of air and water pollution, urban environments and park management, nature protection, pollution associated with agricultural practices, marine pollution, environmental effects on climate, earthquake prediction, environmental education, and legal and administrative measures.
UK	1986	Exchange of information regarding management of hazardous wastes and acid deposition.
		World Heritage Convention; conservation of protected landscapes, undeveloped coastline, and privately owned land; development of long distance trails and voluntary conservation organizations; environmental education; and role of public and private sectors in conservation.
		MOU on Environmental Cooperation.

Note: MOU = Memorandum of Understanding.

The Paris Summit recommended increased international coordination and the implementation of several new activities. An examination of recommendations illustrates the extent to which ongoing U.S. government activities are related to international environmental protection. (See Appendix D for the full text of the environmental declarations from the Economic Summit, Paris, 1989.)

Atmospheric Pollution and Global Climate Change

■ **Summit recommendations:**

- Strengthening the Montreal Protocol on Substances that Deplete the Ozone Layer through the imposition of a total ban on the production of chlorofluorocarbons (CFCs) by the year 2000.
- Giving specific attention to ozone-depleting substances not already covered by the Montreal Protocol and developing suitable CFC replacements.
- Curbing greenhouse gas emissions, acid rain, and deforestation; and increasing bilateral and multilateral activities aimed at curbing emissions of sulfur dioxide and other contributors to acid rain.
- Improving energy conservation and energy efficiency to limit emissions of carbon dioxide (CO_2), one of the "greenhouse gases," and examining alternatives to fossil fuels, such as a new generation of nuclear power plants.
- Increasing scientific efforts to provide a more precise understanding of the processes and extent of global climate change and expanding climate monitoring efforts.
- Supporting the work of the Intergovernmental Panel on Climate Change (IPCC), urging broader international participation, and recommending a framework convention on prevention of climate change.

U.S. agencies have underway a variety of activities that support the recommendations. As follow-up to the Montreal Protocol, the Environmental Protection Agency (EPA) is working with industry to find alternatives to CFCs. EPA also is working with selected developing countries to determine their needs for converting to CFC substitutes and alternative technologies. The Department of Energy (DOE) is considering the economic and energy impacts of phasing out both CFCs and halons.

Regarding greenhouse gas emissions and climate change, the United States participates extensively in the IPCC and has supported other multilateral efforts for the study of climate change. In response to a U.S. proposal, the International Energy Agency is studying the relationship between environmental issues and energy concerns and the impact of various policy responses to climate change on energy markets. DOE activities include evaluating policies and programs to reduce greenhouse gas emissions and to mitigate or adapt to climate change; accelerating research activities to better understand the factors affecting climate change; and promoting research, development, and deployment of new energy technologies. An important DOE contribution will be the National Energy Strategy slated for completion by late 1990.

Other U.S. agencies, particularly the National Oceanic and Atmospheric Administration (NOAA), broadly support international climate monitoring programs. Such programs, carried out primarily by the World Meteorological Organization, offer greater precision in assessing and predicting current and future climatic conditions.

Forest Preservation and Management

- **Summit recommendations:**
  - Encouraging relevant information organizations to complete reports on the state of the world's forests.
  - Protecting biodiversity and rare species native to tropical forests and the traditional rights to land and other resources of local communities through sustainable use.

- Adopting sustainable forest management techniques, implementing the Tropical Forestry Action Plan (TFAP), and supporting financial and technical cooperation to save tropical forests.

- Protecting temperate forests, as well as surrounding streams, rivers, and lakes, from acidic rainfall.

The United States has long supported international forest preservation and management, and federal agencies have been involved in international efforts to promote conservation and sustainable use of tropical forests. The United States participated with the world's tropical timber producing and consuming nations to form the International Tropical Timber Organization (ITTO), the first international commodity agreement to have a conservation mandate. Research on natural forest management for the sustainable production of timber is an ITTO priority.

The Department of State, the USDA/Forest Service, and U.S. AID are participating in the Committee on Forestry of the U.N. Food and Agriculture Organization (FAO). U.S. AID and other U.S. agencies assisted in the development of the global Tropical Forestry Action Plan (TFAP) developed under the auspices of FAO, the World Bank, the U.N. Development Program, and the World Resources Institute. Under that plan, donors and host-country governments will conduct forestry sector reviews in more than 60 countries within the next seven years.The United States also is participating in follow-up efforts to the International Tropical Forestry Strategy Conference, held in July 1987 to further TFAP objectives, and to a subsequent international task force sponsored jointly by the U.N. Development Program, the World Bank, and the Rockefeller Foundation to examine mechanisms for strengthening forestry research throughout the tropics.

In addition, the U.S. Department of Agriculture is assessing the potential of trade in forest products to assist reforestation in Argentina and reforestation and afforestation programs in many U.S. national forests. The DOI/Bureau of Land Management is undertaking reforestation projects on over 160,000 acres in the United States, including projects on 80,000 acres of Indian lands.

U.S. AID efforts in forestry included 150 projects worldwide, including funding for agroforestry, reforestation, natural forest management, fuelwood production, and research. The agency

also is helping countries formulate improved natural resource management policies and development of population policies to stabilize population increases that threaten the fuelwood potential of forests. On an annual basis, about 28 percent of total forestry funding supports reforestation.

The United States, as chair of the IPCC Response Strategies Working Group, has assisted in the activities of the Agriculture, Forestry, and Other Human Activities Subgroup (AFOS), which include workshops on problems of temperate, tropical, and boreal forests.

The World's Oceans

■ **Summit recommendations:**

- ❑ Better international cooperation in developing and adhering to conventions regarding the prevention and cleanup of maritime oil spills.
- ❑ International Maritime Organization (IMO) leadership of international efforts related to oil spills, and relevant U.N.-based groups to produce a comprehensive report on the state of the world's oceans.

The U.S. Coast Guard met with its counterparts from the other G-7 nations to draft resolutions that were proposed at the October 1989 meeting of the IMO in London. IMO accepted both resolutions—one concerning oil spill prevention practices, and the other calling for a November 1990 conference devoted to negotiation of a global oil spill preparedness and response convention.

The DOC/NOAA National Ocean Pollution Policy Board (NOPPB) recently reviewed a report, "The State of the Marine Environment," prepared by the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP). This international group of experts is sponsored jointly by the United Nations, FAO, UNESCO, WHO, WMO, IMO, and the International Atomic Energy Agency (IAEA). Their report describes human impacts on the world's oceans and efforts to prevent and control marine pollu-

tion. The U.S. Department of State requested that NOPPB coordinate an interagency review of the report to determine if it could serve as the comprehensive report suggested by the G-7 nations. NOPPB concluded from its review that the GESAMP report could serve as the basis for the state of the world's oceans report and has offered some recommendations to the U.S. Department of State and the G-7 nations regarding possible actions that can be taken in the future.[32]

Technology Development and Transfer

- **Summit recommendations:**
  - Research and development of clean technologies and transfer of new and existing clean technologies to the developing world.
  - Specific technical requirements demanding the attention of the industrialized world's research and development capabilities: CFC replacements, energy-saving production practices and devices, safe nuclear power generators and other fossil-fuel alternatives, advanced climate monitoring networks, and oil spill cleanup techniques.
  - Prevention of pollution by introduction of production processes that minimize waste of industrial and agricultural inputs, conserve energy, and reduce "end-of-the-pipe" pollution problems. In the industrial sector, this goal would require designing and marketing environmentally benign production technologies. In the agricultural sector, it would include measures aimed at reducing the amount of polluted farm runoff, as well as preventing soil erosion and desertification.
  - Industrialized nations to share state-of-the-art pollution control technologies with poorer and thus often debt-burdened nations.

In 1989 EPA and the Department of State visited a variety of nations—including Brazil, Mexico, and Egypt—to promote transfer of non-ozone-depleting technologies developed by U.S. industries. EPA has provided environmental expertise to Poland, Hungary, China, and Mexico, and it is planning additional activities in the USSR. DOE is working cooperatively with 24 nations to research and develop clean coal and other environmental technologies. A new EPA advisory committee, the International Environmental Technology Transfer Advisory Board (IETTAB), is studying the need for, possible approaches to, and barriers to the transfer of environmental technologies from industrialized to developing nations.

Economics of Environmental Protection

- **Summit recommendations:**
  - Further exploration of the sustainable development concept.
  - Clearer understanding of the effects that consumption taxes and new governmental regulations might have on purchasing habits, and thus on economic growth.
  - A readiness to accord special economic treatment, such as debt refinancing and forgiveness, to developing nations, in order that these nations might develop their economies.
  - The introduction of environmental impact assessments into the application procedures used by the World Bank, the International Monetary Fund, and other multilateral development banks (MDBs).

EPA hosted a January 1990 workshop on the economics of sustainable development in preparation for the May 1990 WCED meeting in Bergen, Norway. DOE is designing the 1990 National Energy Strategy to be environmentally sensitive and to promote coordinated use of the nation's energy resources. Agencies including the Department of State, EPA, DOE, NOAA, and U.S. AID

have jointly proposed use by OECD of environmental indicators that could assess the economic impacts of controlling greenhouse gas emissions.

Recognizing the position of developing nations with respect to environmental protection, several U.S. agencies, including the Department of State, EPA, U.S. AID, and the Department of the Treasury, have urged the World Bank's International Bank for Reconstruction and Development to consider debt-for-nature swaps.

Federal agencies have taken steps to encourage multilateral development banks (MDBs) to incorporate environmental assessments into their lending practices and to allow public access to reports. At the annual meeting of the World Bank and the International Monetary Fund on September 27, 1989, President Bush spoke strongly in favor of such assessments. In discussions concerning the ninth replenishment of funds for the World Bank's International Development Association (IDA), the United States proposed implementation of Environmental Action Plans for all countries using IDA resources. The International Development and Finance Act of 1989 calls for publicly accessible environmental impact assessments from all MDBs receiving U.S. funds, and it encourages debt-for-nature swaps. U.S. AID initiated a review of its Early Warning System, which assesses the impact of proposed loans by international financial institutions long before the loans reach the final approval stage.

Recognizing the intrinsic importance of population to the issue of environmental resource management, the World Bank has announced its commitment to tripling the amount of funding it devotes to population issues. The bank will concentrate on problems in the Third World through use of its concessional loans offered by the International Development Association (IDA). Population stabilization is an area of growing concern as the world population, now totaling 5 billion, threatens to double by the year 2030, further exacerbating resource demand and scarcity.

Notes and References

1. "1989 G7 Paris Economic Summit," paragraph 33, page 1105 in *Weekly Compilation of Presidential Documents* (July 16, 1989).
2. Council on Environmental Quality, *Environmental Quality 1970: First Annual Report*, CEQ, Washington, DC (1970), page 199.
3. CEQ, *1970 Annual Report*, pages 199-200.
4. For example, in 1984 the OECD Council adopted a recommendation concerning information exchange related to the export of banned or severely restricted chemicals. This is one of the activities by various international organizations designed to help countries understand and manage the risks of hazardous materials. Also, UNEP has proposed voluntary notification for banned or severely restricted chemicals. See "Decision 14117 of the Governing Council of UNEP, June 17, 1987," in *UNEP London Guidelines for the Exchange of Information on Chemicals in International Trade, Part II*. A Provisional Notification Scheme for Banned or Severely Restricted Chemicals was adopted by the Governing Council of UNEP in Decision 12/14 of May 28, 1984. FAO has had a similar proposal for pesticides. See FAO, "International Code of Conduct on the Distribution and Use of Pesticides," article adopted by the FAO Conference at its Twenty-third Session in 1985 by way of Resolution 10/85. The concept of "prior informed consent" (PIC) requires participating importing countries to approve the use in their country of a specified banned or severely restricted chemical before it can be imported. The growing popularity of these safer trading techniques can be noted by the fact that in 1989 both UNEP and FAO had taken steps to incorporate PIC procedures within their activities. UNEP adopted the PIC procedure in its Decision 15/30 of May 25, 1989. FAO considered the approval at its November 1989 meeting.
5. Council on Environmental Quality, *Environmental Quality 1985: Sixteenth Annual Report*, CEQ, Washington, DC (1986), page 324.
6. The Soviet Union and its European allies, other than Romania and Yugoslavia, boycotted the conference to protest the fact that since East Germany, unlike West Germany, was not a member of the United Nations, it could not be a full voting participant.
7. *Report of the United Nations Conference on the Human Environment*, Stockholm, June 5-16, 1972, United Nations, New York (1973), pages 3-5.
8. *U.N. Conference Report*, pages 3-5.
9. Jackson, B.W.L., and R.J. Dubos, *Only One Earth: The Care and Maintenance of a Small Planet*, W.W. Norton & Company, Inc., New York (1972), page 220.
10. CEQ, *1985 Annual Report*, page 326.
11. Council on Environmental Quality, *Environmental Quality 1982: Thirteenth Annual Report*, CEQ, Washington, DC (1983), page 220.
12. CEQ, *1982 Annual Report*, page 223.

13. World Commission on Environment and Development (WCED), *Our Common Future*, Oxford University Press, New York, (1987) pages 356-357. The WCED selected eight issues for analysis during the course of its work: (1) Perspectives on Population, Environment, and Sustainable Development; (2) Energy; (3) Industry; (4) Food Security, Agriculture, and Forestry; (5) Human Settlements; (6) International Economic Relations; (7) Decision Support Systems for Environmental Management; and, (8) International Cooperation.
14. WCED, page 4.
15. WCED, page 8.
16. Resolution 42/187, 42 Session of the United Nations, 1987-88.
17. CEQ, *1970 Annual Report*, pages 95-96.
18. Council on Environmental Quality, *Environmental Quality 1981: Twelfth Annual Report*, CEQ, Washington, DC (1982), page 191.
19. *OECD and the Environment*, OECD, Paris (1986), page 5.
20. OECD, page 5.
21. European Coal and Steel Community, 1951; European Economic Community, 1957; and European Atomic Energy Community.
22. Caldwell, L.K., *International Environmental Policy: Emergence and Dimensions*, Duke University Press, Durham (1984), pages 5-7. See also European Community, *The European Community and the Environment, 3d Edition*, EC, Brussels (1987).
23. National Science Foundation, *Loss of Biological Diversity: A Global Crisis Requiring International Solutions*, A report to the National Science Board of the National Science Foundation, NSB-89-171, NSF, Washington, DC (1989), page 1.
24. 16 U.S.C.688 et seq.
25. Council on Environmental Quality, *Environmental Quality 1973: Fourth Annual Report*, CEQ, Washington, DC (1984), page 344.
26. Agreement on the Conservation of Polar Bears, TIAS 8409, (November 15, 1973); CEQ, *1981 Annual Report*, page 204.
27. Caldwell, page 254.
28. *US Department of State Special Report: UN Law of the Sea Conference 1974*, Publication 8764 (May 1974) as reported in Council on Environmental Quality, *Environmental Quality 1974: Fifth Annual Report*, CEQ, Washington, DC (1975), page 446.
29. Caldwell, page 130.
30. International Joint Commission Report (1977).
31. For example, the July 1981 Ottawa Economic Summit noted world interdependence. The May 1984 London Economic Summit called for the environment ministers of the Summit countries and the European Community to evaluate emerging issues and opportunities for future cooperation and to prepare a report on environmental priorities.

    A ministerial meeting held in London the following December stressed the need to integrate environmental and economic decisionmaking. That ministerial meeting identified a number of environmental areas where international cooperation was needed, such as stratospheric ozone depletion, acid deposition, carbon dioxide and climate, the management of toxic chemicals and hazardous wastes, fresh water and marine pollution, resource conserva-

tion, alternative energy strategies, and biotechnology. An Economic Summit Working Group on Technology, Growth, and Employment met three times under the direction of the United Kingdom and prepared a comprehensive report on international environmental problems.

32. Joint Group of Experts on the Scientific Aspects of Marine Pollution, "The State of the Marine Environment," UNEP Regional Seas Reports and Studies 115, UNEP, Nairobi, Kenya (1990).

March 11, 1990

On March 11, 1990, at Barrie, Ontario, 50 people met to kick off a 3-day technical conference on the Great Lakes. The meeting began conventionally enough with a familiar litany of accomplishments and problems in the Great Lakes. The speakers noted that, over the past 20 years, substantial progress had been made in controlling the overenrichment and eutrophication caused by excessive nutrients in the water. The concentrations of some toxic chemicals also had been reduced below 1970 levels. At the same time, many of the fish caught in the Great Lakes still carried enough toxic chemicals in their flesh to render them unsafe for human consumption. And concentrations of some chemicals banned in the Great Lakes region years ago recently had begun to rise.

But this conference was different. For one thing, the participants represented a remarkable range of disciplines and perspectives: water quality and air quality experts, mathematical modelers, fish and wildlife specialists, and federal, state, and provincial regulators. And they were meeting to map out an ambitious project: a strategy for monitoring how Great Lakes water quality was affected by all pollutant sources, including airborne chemicals, urban and farm runoff, and sewage treatment facilities. The participants at the Barrie conference knew it would take all of their skills, applied cooperatively at different levels of government and across borders, to protect the Great Lakes ecosystem effectively.

CHAPTER 8

The Great Lakes

America's greatest surface water resource—the Great Lakes—is one shared with Canada. Ninety percent of the fresh surface water in North America and 18 percent of the world's fresh surface water lie in the Great Lakes. That amounts to 65 trillion gallons or 5,439 cubic miles of freshwater in the five lakes and their tributaries. The lakes and their connecting channels border eight states and two provinces, cover 94,250 square miles, and comprise one-third of the U.S. boundary with Canada. Their coastlines total 9,674 miles, and their watershed covers more than 201,000 square miles. (See Table 8-1.)

Table 8-1.—Physical Features of the Great Lakes.

FEATURES	SUPERIOR	MICHIGAN	HURON	ERIE	ONTARIO	TOTALS
Elevation (meters)	183	176	176	173	74	
Length (miles)	350	307	206	241	193	
Breadth (miles)	160	118	183	57	53	
Average Depth (meters)	147	85	59	19	86	
Maximum Depth (meters)	405	281	229	64	244	
Volume (cubic miles)	2,900	1,180	850	116	393	5,439
Area (square miles):						
Water	31,700	22,300	23,000	9,910	7,340	94,250
Land Drainage Area	49,300	45,600	51,700	30,140	24,720	201,460
Total Area (water plus drainage area)	81,000	67,900	74,700	40,050	32,060	295,710
Shoreline	2,626	1,638	3,827	871	712	9,674

Source: U.S. Environmental Protection Agency and Environment Canada, *The Great Lakes: An Environmental Atlas and Resource Book*, EPA and Environment Canada, Chicago and Toronto (1987), pages 3–4.

"Those Grand Freshwater Seas"

Nineteenth century America writers vied with each other in paying tribute to the immensity of the lakes. Perhaps the most telling literary description comes from an ocean-going sailor in Herman Melville's great American novel, *Moby Dick*, written 150 years ago:

> *For in their interflowing aggregate, those grand fresh-water seas of ours,—Erie, and Ontario, and Huron, and Superior, and Michigan—possess an ocean-like expansiveness, with many of the ocean's noblest traits; with many of its rimmed varieties of races and of climes. They contain round archipelagoes of romantic isles, even as the Polynesian waters do; in large part, are shored by two great contrasting nations, as the Atlantic is; they furnish long maritime approaches to our numerous territorial colonies from the East, dotted all round their banks; here and there are frowned upon by batteries, and by the goat-like craggy guns of Mackinaw; they have heard the fleet thunderings of naval victories; at intervals they yield their beaches to wild barbarians, whose red painted faces flash from out their paltry wigwams; for leagues and leagues are flanked by ancient and unentered forests, where the gaunt pines stand like serried lines of kings in Gothic genealogies; those same woods harboring wild Africa beasts of prey, and silken creatures whose exported furs give robes to Tartar Emperors; they mirror the paved capitals of Buffalo and Cleveland, as well as Winnebago villages; they float alike the full-rigged merchant ship, the armed cruiser of the State, the steamer and the beech canoe; they are swept by Borean and dismasting blasts as direful as any that lash the salted wave; they know what shipwrecks are, for out of sight of land, however inland, they have drowned full many a midnight ship with all its shrieking crew. . . .*
>
> From Chapter 54: "The Town-Ho's Story"

It is no accident that this treasury of natural resources nurtured one of the great centers of industry and agriculture on earth. The "ancient and unentered forests" were entered and cut. The original gaunt pines are gone, but the forest products industry they fostered remains robust to this day. Abundant rainfall and the "rimmed varieties of climes"—really microclimates induced by the lakes—support equally varied agricultural production. One-fourth of Canadian agricultural produce and 7 percent of U.S. produce originate in the basin of the Great Lakes. Unlike other regions of the country, this strong agricultural base requires minimal irrigation.

Industry and cities withdraw vast amounts of water for cooling and process water. Today, one-fifth of U.S. manufactured goods, including 70 percent of this nation's steel production, and 17 percent of U.S. national income are produced in the Great Lakes basin. Almost half of Canadian manufacturing is in Ontario, which borders the Great Lakes.[1]

Waters flowing through the lakes generate almost 45 billion kilowatt-hours of hydroelectric power in the United States and Ontario each year. Some 70 thermoelectric plants on the U.S. side use lake water in steam condensers and for boiler feedwater.

The "long maritime approaches from the East" became longer and more prosperous with the construction of canals and ship channels. The Erie Canal, completed in 1825, linked the port of New York on the Hudson with Lake Erie, thus bringing unparalleled prosperity to both ends. Almost immediately, the cost of goods in the West dropped by 90 percent, while the value of agricultural sales rose sharply. At about the same time, the Canadians opened the Lachine Canal to bypass the rapids on the St. Lawrence River. Then the Welland Canal, joining Lakes Ontario and Erie and bypassing Niagara Falls, was constructed. Canal building culminated in 1959 with completion of the St. Lawrence Seaway, which, while not the commercial success of its predecessors, allows ocean-going vessels direct access to inland America.

The Great Lakes today have become a kind of Northwest Passage, for which so many early explorers searched in vain. Water transport over the lakes remains one of the keys to mid-America's wealth.

Beech canoes still ply the waters, along with vast numbers of other recreational craft. Water-based recreation and tourism in the region is estimated to generate between $8 billion and $12 billion a year. Sport fishing alone accounts for $1.5 billion a year.[2]

Ten percent of the U.S. population and 25 percent of all Canadians live within the Great Lakes Basin, 36 million in all; and 26 million people draw their drinking water from the lakes, which still "mirror the paved capitals of Buffalo and Cleveland," along with Chicago, Detroit, Toronto, Milwaukee, and many other centers of commerce and manufacturing.

But the mirror is not nearly as bright today as it was when *Moby Dick* was written.

Troubled Waters

The growth of the economy and population in the Great Lakes region has been accompanied by a decline in the quality of the environment that nurtured them. The history of the commercial fishing industry is especially telling. Commercial fishing began in the Great Lakes in 1820, reaching its peak harvest of 147 million pounds in 1899, almost 100 years ago. Even at that time, some of the most valuable species in Lake Erie were in decline. By 1950 the industry had shrunk. Today the average annual yield is 110 million pounds and the value of the catch has declined sharply as the larger and more valuable fish have given way to smaller, less desirable species.

Five of the most valuable species of the early commercial fishery were lake trout, lake whitefish, grayling, and blue pike in Lake Erie, and the Atlantic salmon in Lake Ontario. Today lake trout, once the top predator of the lakes, survives in sufficient numbers for commercial fishing only in Lake Superior. Even there, natural reproduction must be supplemented by hatcheries. The blue pike and grayling of Lake Erie are believed to be extinct. The same is true of Ontario's Atlantic salmon. Commercial fishermen continue to catch lake whitefish, but only in Lake Superior and parts of Lakes Michigan and Huron.[3]

Overfishing, pollution, destruction of habitat, and the introduction of exotic species such as the sea lamprey all contributed to the decline of the commercial fishery. Toxic chemicals that render fish unsafe to eat have added a new burden to the industry and the measure of wealth it produces. The same is true for the "silken creatures whose exported furs give robes to Tartar Emperors." One hundred and fifty years after those words were penned, minks and otters have disappeared from portions of the shorelines of Lakes Michigan,[4] Huron, and Superior,[5] where they once were abundant.

Rescue

During the last 20 years, the United States and Canada, those "two great contrasting nations," have worked cooperatively to reduce the stress on the lakes and restore their ecological health and abundance. The "guns of lofty Mackinaw" have been upstaged by sewage treatment plants. The "armed cruiser of the State" has given way to government research vessels. The two nations have spent billions on new sewage systems and pollution controls; they have ratified unprecedented international environmental agreements; they have enacted and enforced strict national, state, and provincial laws.

Those efforts paralleled and in some respects pioneered clean water programs across the nation. The Great Lakes water quality program is a large canvas on which one can see both the success and failure of much of America's environmental protection efforts over the last two decades. And there, too, can be seen hints of the prospects for future improvements in the decades to come.

An additional reason for looking closely at the Great Lakes in 1989 is the fact that they are international waters. As the 20th century draws to a close, problems of the global environment attract public attention. Ozone depletion, the greenhouse effect, massive deforestation, exports of hazardous materials, and similar concerns have become major foreign policy issues.

Although intense efforts now are being made to establish frameworks for international cooperative ventures to preserve aspects of the global environment, successful historical examples are few. Yet one excellent example of nations working together to protect and preserve a common natural resource is the U.S.–Canadian Great Lakes Water Quality Agreement and its predecessors.

Historical Perspective

The 1968 annual supplement to the *World Book Encyclopedia* contained a special report entitled, "The Killing of a Great Lake," which, like many other general news reports, scientific studies, and government documents of the late 1960s, sounded alarms about the impending death of Lake Erie:

> *In some parts of the lake, the waters are a murky green from algae that thrive on the wastes dumped into the water. During the summer months, the western basin of Lake Erie contains a mass of algae that sometimes covers 800 square miles and has a thickness of two feet.*
>
> *The variety of floating and rotting wastes is a constant reminder that man can indeed kill a lake. . . .*
>
> *The lake is threatened with death. It is slowly choking from its heavily polluted tributaries and shoreline. Water experts warn there is little relief in sight. Some even say the lake is dying so fast it will soon be an aquatic desert—America's Dead Sea.*[6]

At about the same time, the Food and Drug Administration embargoed 39,000 tons of coho salmon caught in the Great Lakes because of elevated levels of DDT in the fish tissue. A year later, the Canadian government banned sale of fish caught in Lake St.

Clair and Lake Ontario because of dangerous mercury contamination.

Wildlife also showed the effects of toxic chemicals. Bird populations, which had been visible elements of the lakescape for thousands of years, began declining. Reproduction rates in certain types of birds, especially those that eat fish, fell precipitously. Fewer eggs were laid, and many of those eggs never hatched. A significant percent of living hatchlings showed evidence of deformities,[7] many of which were extremely rare or unknown prior to 1950. A growing number of avian deformities were noticed during the 1950s and 1960s.

Those effects were strongly associated with the presence of toxic chemicals in the tissue of the animals.[8] Elevated levels of industrial and agricultural chemicals and metals were found in the eggs of fish-eating birds, such as the herring gull, and in the fatty tissues of large predator fish, such as the lake trout or salmon.

Twenty-two years after those alarms were sounded, Lake Erie is anything but a Dead Sea. It and the other Great Lakes have undergone major transformations, many of them for the better. After extraordinary effort and expense, the choking condition known as eutrophication has abated to a remarkable degree.

The campaign to eliminate the problems of toxic chemicals likewise has been somewhat successful. However, new and vexing problems related to toxic pollution have been identified. The fate of water birds on the lakes over the last several decades illustrates a disturbing pattern.

During the 1950s and 1960s, bird populations began to decline rapidly. Scientists now believe that the radical population declines were precipitated by the widespread use of DDT and related compounds. Chemical pesticides interfered with the ability of birds to form egg shells, thereby cutting deeply into rates of reproduction. DDT and dieldrin, another agricultural chemical affecting bird reproduction, were banned in the late 1960s, and bird species that had been in great jeopardy soon regained their former numbers.[9]

It now appears, however, that the DDT hid an underlying problem related to PCBs, a more pervasive toxic chemical. Just as observers began to celebrate the increasing bird populations, they also began to notice an escalation in bird deformities, including cross bills (where the upper and lower bills do not close

properly, making survival difficult), lack of jaws, lack of skull bones, lack of feathering, club feet, improper insertion of tendons in the leg, rotated ankles, dwarfed appendages, unabsorbed yolk sac in late development embryos, severe subcutaneous edema on the head, neck, or abdomen, liver troubles, low birth weight, and other similar conditions.[10] During the last 25 years, the frequency of such occurrences has grown by two orders of magnitude,[11] which suggests a fundamental change in the Great Lakes ecosystem.

The Great Lakes Today

In 1972 the governments of the United States and Canada instituted a joint program to combat the eutrophication problem in all five of the Great Lakes, with emphasis on Lakes Erie and Ontario. In 1978 the governments further agreed to begin addressing for the first time the problem of toxic contamination.

An Ecosystem Approach

A central purpose of the two nations, as first expressed in the 1978 Great Lakes agreement, ". . . is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem."[12] The idea of the "Great Lakes Basin Ecosystem" is one of the keys to the success of the binational water quality program in the Great Lakes, and it represents the best hope for overcoming past shortcomings.

Institutions

The Water Quality Agreement between the United States and Canada is one of very few such agreements to commit the signatories to an ecosystem-wide approach to solving water quality problems. The parties agreed not to let national or state boundaries deter them from seeking the causes and cures of Great Lakes problems, because those problems, like airborne water pollution, were not defined by national boundaries.

At the same time, the ecosystem approach does not mandate centralization of control at ever higher levels of government. Indeed, the growing consensus among U.S. and Canadian representatives is that:

> *. . . the [federal] style of environmental regulation may not be the most appropriate for the complex water quality problems faced in the Great Lakes Basin Ecosystem today. . . . [L]ocal government officials and local plant management [should assume] a central role in the articulation of the problem, selection of the appropriate response, and implementation of the solution. [I]mportant decisions in environmental control systems ought to be as close as possible to the location where the physical consequences of the decision will be felt.*[13]

What the ecosystem approach does mandate is coordinated, integrated action by all responsible parties—federal, state, provincial, and local governments, the private sector, and indeed, individuals themselves. Recognition that all parts of the problem are connected leads directly to the conclusion that solutions must be integrated as well.

Like the ecosystem itself, the institutions that govern the lakes are and have been in flux. In 1909 the United States and Great Britain signed a historic agreement managing the waters between the United States and Canada. One of the provisions of the International Boundary Waters Treaty stated:

> *It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other.*

The treaty established a board of U.S. and Canadian representatives, known as the International Joint Commission (IJC), to mediate and make recommendations for settling such disputes and questions as the governments might refer to it. Great Lakes water quality soon became an issue. In 1912 the two governments asked the commission to study the pollution problems of the lakes as well as other boundary waters. Six years later, the IJC reported that the water quality "... situation along the frontier is generally chaotic, everywhere perilous and in some cases disgraceful." The commission recommended the elimination of industrial pollution and a minimum level of treatment for all municipal sewage systems. It also recommended that the commission itself be given authority to regulate pollution in the boundary waters as a whole.

That first attempt at ecosystem management was rejected by the two governments. Instead, the individual municipalities looked to their own interests by chlorinating the waters drawn from the lakes for drinking. That step almost eliminated typhoid fever from the lakes region, but it did nothing to relieve the growing illness of the ecosystem as a whole.

In the late 1940s the unsightly and unhealthful condition of the Detroit River, Lake St. Clair, the St. Clair River, and later the Niagara River prompted the two nations to seek advice again from the IJC. In 1951 the commission reported back that the bacteriological problems in the lakes had gotten three or four times worse than they were in 1918. Industrial contaminants such as oils, phenols, cyanides, and oxygen-demanding materials were "now a major problem." Therefore the Commissioners recommended an international agreement on a set of water quality objectives and establishment of a board to monitor progress towards the objectives. That modest recommendation, which covered only the connecting channels, was adopted by both nations, thus marking the beginning of a continuous IJC involvement with Great Lakes water quality.

In 1964, in response to widespread public concern, the governments of the United States and Canada asked the IJC to examine, in detail, water quality in Lake Erie and Lake Ontario. The commission reported in 1970 that both lakes were seriously polluted as a result of municipal and industrial discharge and that all jurisdictions surrounding the lakes were contributing to

the problem. The commission recommended the following actions:

- Adoption of general and specific water quality objectives,
- Immediate reduction of the phosphorus content in detergents, and
- Development of municipal and industrial waste treatment facilities.

The commission also recommended that the governments enter into appropriate international agreements to deal with the serious pollution issues that had been identified. The U.S.–Canadian response was the 1972 Great Lakes Water Quality Agreement, which addressed all of the issues raised by the IJC in its report.

As the years passed and the state of the lakes continued to decline, the scope of IJC oversight expanded. Nonetheless, the primary responsibility and authority for water quality regulation resided with state and provincial governments. The focus of responsibility shifted with passage of the Federal Water Pollution Control Act of 1972. That legislation, while acknowledging state primacy, established a large new federal regulatory program backed with federal grant-making authority. It also encouraged stronger state regulatory programs, through direct financial aid and a variety of delegations and regulatory mechanisms. The presence of a creditable federal enforcement program lent authority and resolve to state regulators.

The Clean Water Act amendments of 1981 and 1987 returned a good deal of responsibility to the states, especially financial responsibility. At the same time, state, provincial, and municipal governments began developing new institutions to meet new challenges. For example, the Great Lakes Charter, signed in the mid-1980s, committed the governors and premiers of Great Lakes states and provinces to consult with one another before permitting diversions of water outside the basin. Later the parties agreed to cooperate on remediation of toxic pollution. The eight Great Lakes governors recently established a $100 million Great Lakes Protection Fund for the purpose of endowing a long-term program of pollution research, demonstration, and cleanup projects. The State of New York and the Province of Ontario have

reached a new accommodation that has begun to relieve environmental problems along the Niagara River.

One issue that tends to foster a regional consciousness is the question of water diversions and consumptive uses. At a time when predictions of global climate changes have become commonplace, people in the Great Lakes region are beginning to appreciate as never before the enormous wealth represented by the world's largest reservoir of fresh surface water. In periods of drought, water-short areas tend to look for Great Lakes water. For example, in 1987 when water levels on the Mississippi River fell so low that navigation was stopped, southern states and industries called for larger releases of Great Lakes water, provoking quiet protests from Canada. In a 1985 report on diversion and consumptive uses, the International Joint Commission urged the two governments to engage in ". . . broad but systematic discussions of their use of Great Lakes water before they are faced with any sense of crisis, actual or imminent, and before any relationships deteriorate or become jeopardized."

Science

The ecosystem approach also involves a higher level of site-specific scientific investigation than is typically the case in water regulatory regimes. Most Great Lakes cities and many industries are in compliance with uniform national discharge standards. While that has helped to alleviate pollution problems, it has by no means solved them.

A key technique for site-specific investigation is the mass balance study. The mass balance approach relies on the law of conservation of mass, that is, what goes in must come out. More formally, the quantity of contaminants entering the system from all sources, less quantities stored, degraded, or transformed within the system, must equal the quantities that leave the system. Thus mass balance studies help account for the source, transport, and fate of contaminants. This accounting is used the way a business might use a year-end financial report: to evaluate progress, set priorities, and allocate resources. Such a technique was used in the 1970s to devise a strategy for reversing the

process of eutrophication by controlling phosphorus, a strategy that proved to be remarkably successful. The two national governments now are attempting to do the same thing for toxic contamination, a more difficult and expensive undertaking.

Federal, state, and local agencies have conducted mass balance investigations of the rivers and channels that connect the Great Lakes to one another, and they are now engaged in a major mass balance study of Green Bay. Although funding for such work is limited, mass balance studies promise to be useful tools in deciding how limited resources might best be spent.

Ecosystem Ills

Both eutrophication and toxic contamination are affecting the health and biology of the Great Lakes ecosystem.

Eutrophication

Eutrophication in the Great Lakes is characterized by explosive growth of blue-green algae in the spring and summer. Over the course of the year the algae dies off and settles to the bottom. As it begins to rot, it consumes the available oxygen in the water. The depletion of oxygen and the blockage of light destroys the conditions necessary for a diverse population of fish and aquatic vegetation. The odors associated with severe eutrophication make the water unsuitable for drinking or recreation.

The word eutrophication comes from two Greek words meaning well-nourished. An increase in the amount of nutrients or fertilizers entering the water brings about an alteration in the production of microscopic plants, known as phytoplankton.

Phytoplankton are the first link in the food chain. Those microscopic algae are to the lakes what grass is to the prairie. They convert sunlight, nutrient salts such as phosphates and nitrates, carbon, oxygen, and other chemicals into living material. The phytoplankton in turn are eaten by microscopic animals

or zooplankton, which are preyed upon by small fish, which are eaten by bigger fish, which are eaten by birds, animals, and humans. Conditions that alter the phytoplankton must eventually affect all other organisms, including man.

From a technical point of view, the dying Lake Erie was in fact teeming with life. Indeed, in terms of the sheer weight and volume of living matter—so-called biomass—the lake probably was more productive in the late 1960s and early 1970s than at anytime in its history.[14] Yet most of that living material was at the bottom end of the food chain and was not cycling up. In terms of its function as a home for a diverse population of flora and fauna, the lake was in poor condition.

The Great Lakes are endowed with a number of natural defenses against eutrophication. The drainage area of the lakes is relatively small in comparison to the area of the lakes themselves. Less land area means less erosion. Secondly, much of the drainage area along the northern shores of the upper lakes, which is still forested, is composed of bedrock that weathers slowly, adding few nutrients to nourish either land or aquatic plant life. The very hard igneous and metamorphic rocks that form the basins for Lake Superior and the Georgian Bay of Lake Huron are part of a geological formation known as the Canadian Shield. Although the soils around the lower lakes are more erodible and richer in nutrients, in presettlement times they were held in place by a dense "unentered forest."

Thus, before settlement by Europeans, water quality in the Great Lakes was very close to the quality of pure rain. Of the major nutrients necessary for algal growth, only nitrogen was present in excess. The waters were originally poor in silica, and they contained very little phosphorus. They were rich in oxygen and poor in nutrients. The scientific term for this condition is oligotrophic, or undernourished—the opposite of eutrophic.

Another factor that helped to maintain the purity of the lakes was their extraordinary temperature regimes. The lakes are divided into rather distinct layers or strata based on temperature. The deepest layer, called the hypolimnion, maintains a more or less constant temperature throughout the year of 4°C (39°F), the temperature at which water has the greatest density. During summer, the upper layer, or epilimnion, may reach 18°C (61°F) in northern waters and as high as 27°C (80°F) in Lake Erie, while

the bottom layer rarely exceeds 6°C (42.8°F) throughout the system. In the fall, as the surface water temperature approaches 4°C, it sinks to the bottom, mixing water, oxygen, nutrients, and plants, a phenomenon known as fall turnover.

In winter, ice forms and breaks up on the surface, but the hypolimnion maintains its constant temperature. With spring thaw comes another turnover.[15] Such turnovers help to replenish the oxygen at the bottom of the lakes. The stratification tends to limit the dispersion of pollutants throughout the year. Thus, during spring, the shallow waters near shore warm up much faster than the deep waters in the center of the lakes. A narrow zone between the warm shore waters and the cool deep waters develops. This zone, known as the thermal bar, acts like a curtain that restricts the movement of organic materials fed into the lakes by streams during the spring. The summer stratification also tends to restrict the movement of pollutants in the lakes.[16]

Those conditions in the pristine lakes produced an array of microscopic plants and animals that sustained a unique diversity of fish and wildlife. The most abundant type of algae were the diatoms, which thrived in the low temperatures and low phosphorus levels typical of the upper part of the hypolimnion. Unlike other algae, diatoms are dependent upon silicon dioxide, which forms their walls. Diatoms flourished in the lakes during all seasons of the year, providing a constant food supply. The thermal bar confined nutrients to the large shallow embayments—western Lake Erie, Saginaw Bay in Lake Huron, Lake Michigan's Green Bay—which ". . . tended to have floras similar to those found on smaller lakes, with their nutrient-rich streams and shallow water readily mixed by wind action. These embayments produced a great many primary producer organisms and, in turn, many fish."[17] The Great Lakes had the best of both worlds.

Fish, clear water, easy water transport, and the other benefits of the Great Lakes region encouraged human settlement. Those settlements, in turn, led to the environmental changes so much in evidence two decades ago.

Human settlement stimulated a huge increase in the quantity of nutrients reaching the open waters of the lakes. The phenomenon was evident first in Lake Erie and Lake Ontario. The soils around those lakes were naturally richer and more erodible than lands around Lake Superior and Lake Huron. The

conversion of forest tracts to farmland accelerated the processes of erosion and over-enrichment. The lower lakes also attracted the most people and the greatest degree of urbanization and industrialization. Industrial effluent and especially human sewage injected huge doses of phosphorus and nitrogen—both of them nutrients—into the lakes.

A number of nutrients are necessary to support life, just as a number of fluids—oil, gasoline, transmission fluid, water—are needed to propel an automobile engine. To slow the pace of growth, it is only necessary to limit one of them. Scientists and regulators determined in the 1960s that limiting phosphorus would be the most effective and economical means of controlling eutrophication.

High phosphorus levels in the Great Lakes increased the quantity of phytoplankton, which in turn absorbed much of the available nitrogen in the water column. This gave a great advantage to blue-green algae, which alone among the algae are able to take the nitrogen they need from the atmosphere. Blue-green algae tend to float on the surface of the lakes, blocking the light so that diatoms indigenous to the deep waters can no longer survive. As a consequence of this change in the food base, zooplankton populations feeding in the upper stratum, or epilimnion, prosper at the expense of deepwater species. This change, in turn, favors invading fish species, such as alewife, at the expense of the indigenous chub, cisco, and lake herring. The balanced food supply that had prevailed in the Great Lakes for the previous 10,000 years, with algal productivity taking place almost constantly through much of the water column, was replaced by a seasonal cycle of blooms and crashes—massive die-offs—of surface algae.[18]

Eutrophication is sometimes thought of as a natural process, akin to aging, whereby rivers and lakes turn into swamps and then dry land over the course of thousands of years. But aging is an irreversible process. It moves in only one direction, whereas eutrophication can be reversed. Scientists who have studied the fossilized records of ancient lakes believe that the fertility of lakes changes as the watershed changes, becoming more or less fertile as the surrounding land is changed by alterations in climate or other factors.[19] Indeed, the critical factor leading to eutrophication in the Great Lakes was human activity through-

out the Great Lakes watershed. Yet because of changes in human activity over the last 20 years, the process of eutrophication on the Great Lakes has been halted, at least temporarily, and in some cases has been reversed.

Toxic Chemicals

The problem of toxic contamination in the Great Lakes has proven more intractable. About 30,000 chemical compounds are used in the Great Lakes Basin today, and an additional 1,000 new chemicals are developed each year. By 1987 the United States and Canada had verified the presence in the Great Lakes of 362 compounds with a high potential for toxicity.[20]

The toxics problem in the Great Lakes is similar to the eutrophication problem in that it is a condition affecting the whole interrelated system of living things. Here again, the problem begins with the phytoplankton, the building blocks of life. When these tiny creatures process even minute quantities of some toxic chemicals, they can absorb them and then pass them on through the food chain to insects, fish, animals, and humans. That process is known as biomagnification, and it is a key concept for understanding toxic chemicals in the Great Lakes.

At the "bottom" of the food chain, phytoplankton are equipped by nature to scour huge volumes of water to collect nutrients found in very low concentrations. In the process of collecting nutrients, they may also collect persistent man-made chemicals, such as pesticides. The concentration of such chemicals in living cells can become very high, even though concentrations in the water may be below the level of detection. Zooplankton and small fish eat great quantities of phytoplankton, further concentrating the persistent chemicals. The large fish eat the smaller fish, and the birds eat the larger fish. At each step up the chain, the concentration of chemicals can increase by orders of magnitude. Toxic residues have been observed in Great Lakes birds at levels that were 25 million times the levels found in the open waters.[21]

Near the top of the food chain are the bald eagles, which eat fish and fish-eating gulls. The eagle is sometimes considered one

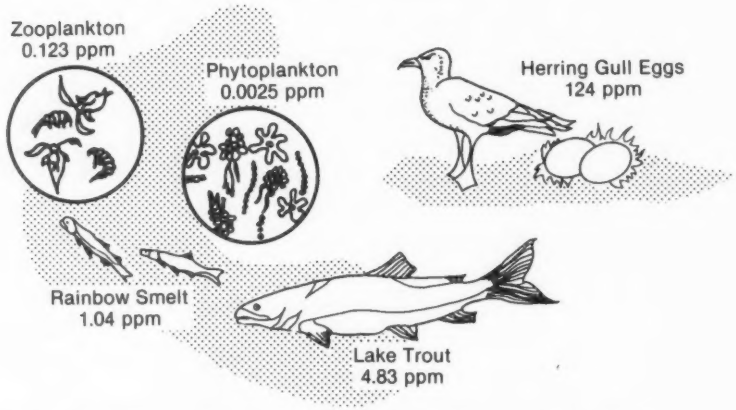
of the best barometers of the chemical health of the lakes. In general, when the predator at the top of the food chain is reproducing and thriving, ecologists consider the overall ecosystem to be healthy as well.[22] In the 1980s bald eagles nesting near the Great Lakes were reproducing at about half the rate of bald eagles five miles inland.[23]

Health and Biological Effects

Many of the chemicals of most concern to human health tend to accumulate in fatty tissues. Thus large fatty fish, egg yolks, and mother's milk tend to become depositories of these chemicals.

Great Lakes scientists have investigated the accumulation of toxic chemicals in the eggs of the herring gull, a fish-eating bird that dwells in large numbers near the lakes. Figure 8-1 illustrates how one of the most persistent and troublesome chemical groups, PCBs, is almost 50,000 times as concentrated in herring gull eggs as it is in phytoplankton. Once chemicals of this kind enter an organism, they tend to stay there for years.[24]

Figure 8-1.—Concentrations of PCBs Biomagnified in the Aquatic Food Chain of the Great Lakes.



Source: U.S. Environmental Protection Agency and Environment Canada, *The Great Lakes: An Environmental Atlas and Resource Book*, EPA and Environment Canada, Chicago and Toronto (1987).

Toxic chemicals in fish have begun to produce detectable effects in human beings who live near the lakes. In 1975 scientists noticed an elevated level of PCBs in people who frequently ate Great Lakes fish.[25] In 1980 Canadian and U.S. scientists concluded that this condition could cause adverse health effects.[26] Pregnant women, infants, and small children were considered to be at particular risk. One ground-breaking study compared infants of women who regularly ate fish from Lake Michigan to infants of women in the same area who did not eat fish. The former group experienced significantly higher incidences of low birth weight and delayed intellectual and physical development.[27] A follow-up study of the same infants at the age of four showed that those who took in higher levels of PCBs from the mother's placenta exhibited poorer short-term memory than those exposed to less PCBs in the womb.[28] Ingestion of the same chemicals through breast milk did not produce a similar effect, even though the quantities involved were significantly higher in the milk.

Due to toxic contamination, all of the Great Lakes states and provinces have issued health advisories about eating lake fish. Table 8-2 lists Great Lakes fish consumption advisories.

The advisories from the various states are not always consistent. The same amount of the same fish is considered safe in one state and unsafe in another. Clearly, considerable scientific uncertainty remains as to what levels of which chemicals trigger human health effects.

Moreover, recent scientific information has not yet been fully integrated into state and federal regulatory processes. For example, fish consumption advisories are not always based on the most current understanding of the health impacts of PCBs.

Polychlorinated biphenyls (PCBs) are colorless, odorless chemicals widely used in electrical equipment and other industrial applications. Before they were banned in 1976, 1.4 billion pounds were produced in this country.[29]

PCBs are composed of 209 separate compounds, known as congeners or isomers.[30] Each of these congeners exhibits a different degree and type of toxicity, bioconcentrates at different rates, and generally behaves differently from the others in the environment.[31] Some PCB isomers are a million times more dangerous than others. Yet some state health departments are not equipped to distinguish between the different isomers. They

Table 8-2.—Great Lakes Public Health Fish Consumption Advisory, 1987.

AREAS	RESTRICT CONSUMPTION*	DO NOT EAT
Lake Michigan** (Michigan, Illinois, Indiana, and Wisconsin waters)	Lake Trout 20–23″, Coho Salmon over 26″, Chinook Salmon 21–32″, and Brown Trout up to 23″	Lake Trout over 23″, Chinook over 32″, Brown Trout over 23″, Carp, and Catfish
Green Bay** (Wisconsin waters south of Marinette/Menominee)	Splake up to 16″	Rainbow Trout over 22″, Chinook over 25″, Brown Trout over 12″, Trout over 15″, Splake over 16″, Northern Pike over 28″, Walleye over 20″, White Suckers, White Bass, and Carp
Lake Superior (Michigan, Wisconsin, and Minnesota waters)	Lake Trout up to 30″, Walleye up to 26″ (Wisconsin waters)	Lake Trout over 30″, Walleye over 26″ (Wisconsin waters)
Lake Huron**	Lake Trout, Rainbow Trout, and Brown Trout	—
Saginaw Bay	Lake Trout, Rainbow Trout, and Brown Trout	Carp and Catfish
Lake Erie**	Carp and Catfish (New York waters—eat no more than one meal per month)	Carp and Catfish (Michigan, Ohio, and Pennsylvania waters)
Lake Ontario** (New York waters)	White Perch, Coho Salmon up to 21″, Rainbow Trout up to 18″ (eat no more than one meal per month)	American Eel, Channel Catfish, Lake Trout, Chinook Salmon, Coho Salmon over 21″, Rainbow Trout over 25″, Brown Trout over 18″
Lake St. Clair (Michigan and Ontario waters)	Walleye over 18″, White Bass over 14″, Smallmouth Bass over 14″, Yellow Perch over 12″, Carp over 22″, Rock Bass over 8″, Black Crappie over 10″, Largemouth Bass 12–13″, Bluegill and Pumpkinseed over 8″, Freshwater Drum over 12″, Carpsucker over 18″, Brown Bullhead over 10″, Catfish over 22″, and all Northern Pike	Largemouth Bass over 14″, Muskie, and Sturgeon
St. Clair River (Michigan and Ontario waters)	Gizzard Shad over 10″	—
Detroit River	—	Carp

*Also applies to tributaries into which migratory species enter.
**Nursing mothers, pregnant women, women who anticipate bearing children, and children age 15 and under should not eat the fish listed in any of the categories listed above.
Source: Great Lakes Water Quality Board, *1987 Report on Great Lakes Water Quality: Report to the IJC*, International Joint Commission, Windsor, Ontario (March 1980).

base their health warnings and reassurances on total PCBs. A number of biologists and toxicologists believe that state toxics monitoring programs, based on total PCBs, are "completely meaningless" and "provide reassurance to the public that is wholly unwarranted."[32]

Moreover, the states and the federal Food and Drug Administration base many of their warnings on PCB levels in fish because of the threat of cancer. While cancer is a serious concern, a more immediate and perhaps more severe problem may be related to birth defects and reproductive failures.[33] In fact, the studies of infants and young children whose mothers ate PCB-contaminated fish from Lake Michigan suggest that reproductive failures and birth defects may be the human health effect of most immediate concern in the Great Lakes area.

A set of experiments involving the Forster's tern, a common Great Lakes nesting bird, illustrates the effects of PCB isomers on the process of birth. In one experiment, 20 eggs were collected from each of two colonies. One colony was located at Green Bay in Lake Michigan, an area contaminated with a variety of pollutants; the other was located at Lake Poygan, Wisconsin, a relatively clean, inland lake. The eggs were artificially incubated. Twice as many live chicks were hatched from the Lake Poygan eggs as from the Green Bay eggs. It took 4.6 days longer for the Green Bay eggs to hatch. Despite the longer incubation period, the Green Bay eggs weighed 22 percent less than the Lake Poygan eggs. Two Green Bay embryos were abnormal: one had a crossed beak and the other had a poorly ossified foot and a short lower beak. A hatched chick from the Green Bay group had abnormal bone structure. The Green Bay chicks had enlarged livers and abnormally high liver enzyme activity.

A second experiment demonstrated that adult terns from contaminated regions abandoned their nests and lost their eggs more frequently than their inland cousins. The PCB isomers identified in those experiments impaired the eggs as well as the breeding behavior of the parents.[34] These kinds of chemically induced effects on fish and wildlife may be on the rise. Recent monitoring data indicate that the overall effects of toxic chemicals are increasing in colonial waterbirds, even though the concentrations of toxic chemicals in the water are declining.[35] Fish tumors and other evidence of toxic contamination are common. Mink and otter have all but disappeared from large sections of

the Great Lakes shoreline, especially Lake Michigan,[36] probably due to reproductive failure.

The Science Advisory Board of the International Joint Commission is encouraging the U.S. and Canadian governments to carry out a comprehensive binational investigation of the significance, nature, and extent of human exposure to toxic chemicals in the Great Lakes. The Board believes that the fish and wildlife populations already have sent a clear danger signal regarding human health and safety. Consequently, scientists have begun to develop models for the movement of contaminants and toxic effects through the food chain.[37] Of special concern are the effects of toxic chemicals on reproduction and on the health of juvenile members of species, including human beings.

The Conservation Foundation and the Institute for Public Policy recently completed a major study of the Great Lakes. That report stated:

> *. . . there may be subtle effects on human health that have gone largely undetected and that stem from contaminants in the food web. Certain identifiable subgroups of the population appear to be at elevated risk of exposure. These include human embryos, infants and children whose parents have bioaccumulated substantial quantities of toxic chemicals that exist in fish and waterfowl. The health effects in the offspring may include altered cognitive, motor, and behavioral development. Preliminary studies suggest that these subtle effects may be far more significant among at-risk populations than cancer and gross physical defects. The need for "more data" is urgent.*[38]

Ecosystem Remedies

Pollution control efforts in the Great Lakes Basin have attempted to reduce the discharges of contaminants from point and nonpoint sources. The emphasis has been on phosphorus, but other nutrients, such as nitrogen, also have received attention.

Moreover, in recent years toxic contaminants have become a major problem, and their control a challenge.

Nutrients

By 1972 the eutrophication problem in the Great Lakes had become so severe that the United States and Canada agreed to an aggressive program of phosphorus reduction in the lower lakes. By 1983 the two governments had agreed on target phosphorus loads for all the lakes and on reductions by each country in all lakes but Lake Ontario.

Point Source Controls: Phosphorus

Controls on the amount of pollutants that are discharged from the pipes of factories and municipal sewage plants are known as point source controls. During the last 20 years, governments on both sides of the border have spent billions of dollars on sewage facilities to sharply reduce point source phosphorus discharges. Table 8-3 shows statistics on phosphorus discharges from municipal sewage treatment plants for each year between 1975 and 1985.[39] In 1975 U.S. municipal governments discharged more than 6,700 metric tons of phosphorus into Lake Erie. Ten years later phosphorus discharges had declined to less than 2,200 tons. Private industry, spurred by new regulations, also achieved significant reductions.

The effort to reduce phosphorus discharges was aided further by bans on household detergents containing phosphates. All the Great Lakes states except Ohio and Pennsylvania have had phosphate bans for a number of years. Ohio passed a phosphate law in 1988, and Pennsylvania's phosphate ban was enacted in 1989. The Province of Ontario also has a phosphate law, but it is much less restrictive than its U.S. counterparts.

Federal and state governments in the Great Lakes states have issued more than 2,500 pollution control permits to private industry and more than 1,100 to municipal governments. Most of the permits contain phosphorus limits, and most of the recipients are in compliance with their permits.[40]

Table 8-3.—Municipal Phosphorus Loadings Reported in the Great Lakes Basin, 1975–85.

LAKE BASIN	1972 ESTIMATE	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
						*metric tons/year**						
SUPERIOR												
United States		224	222	154	142	83	94	70	64	85	89	94
Canada		62	71	108	97	124	109	100	115	68	58	53
MICHIGAN												
United States		2,325	2,336	1,660	1,314	1,224	1,047	934	885	928	919	894
HURON												
United States		414	370	340	273	227	232	244	248	219	205	201
Canada		210	208	217	222	217	195	231	168	216	243	261
ERIE												
United States	13,870	6,719	5,578	6,147	5,250	4,000	3,287	2,642	2,199	2,356	2,499	2,176
Canada	1,390	232	262	259	228	234	213	232	250	274	268	273
ONTARIO												
United States	4,750	1,847	1,815	2,089	1,761	1,788	1,535	1,194	1,166	1,005	872	772
Canada	5,110	2,373	1,267	1,000	967	1,110	977	1,014	949	906	952	938
ST. LAWRENCE RIVER												
United States		37	58	50	59	47	86	131	121	145	158	131
Canada		123	89	129	128	94	76	74	78	52	54	52

*United States data and 1985 Canadian data are for water year. Earlier Canadian data are for calendar year.
Source: Great Lakes Water Quality Board, *1987 Report on Water Quality; Report to the IJC*, International Joint Commission, Windsor, Ontario (March 1980).

The point source control effort in the Great Lakes has changed the chemical nutrient balance of the lakes. In 1974 the concentration of phosphorus in the open waters in the eastern basin of Lake Erie was a little more than 20 micrograms per liter (20 μg/L), a concentration that could stimulate unwanted blooms of algae. By 1989 phosphorus concentrations had been reduced by about half to just slightly above the safe level of 10 micrograms per liter (10 μg/L). Figure 8-2 illustrates the decline in phosphorus levels in eastern Lake Erie, Lake Michigan, and Lake Ontario, and it projects future phosphorus levels.

The general public has been able to see that the phosphorus reduction program of the last two decades has succeeded. The vast rotting masses of blue-green algae that so alarmed the United States and Canada have not been seen in recent years. Lake Erie's return from the "dead" has become a standard text of environmental progress. Valdas Adamkus, current Great Lakes Program Manager and regional administrator of EPA Region V, describes the progress this way, "We have not solved the eutrophication problem, but we have brought it under control."[41]

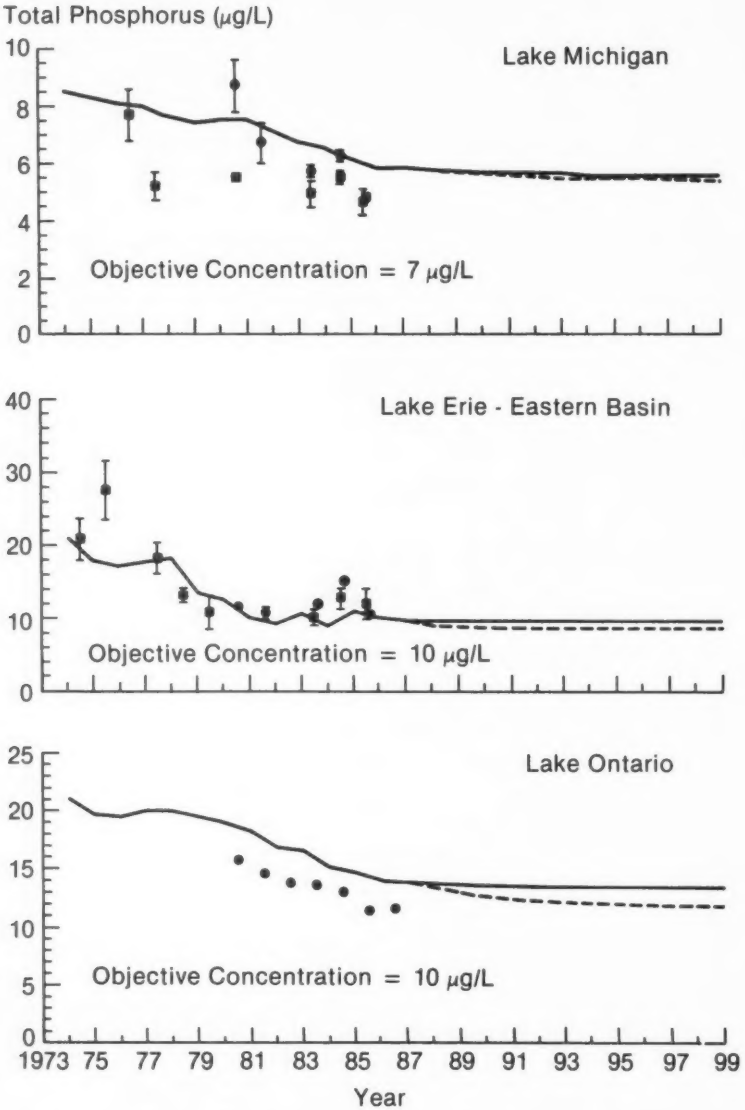
Nonpoint Source Controls: Phosphorus

Most of the progress in reducing nutrients in the Great Lakes resulted from controls on large, discrete pollution sources, especially municipal sewage treatment plants and factories. But large centralized facilities are not the only sources of nutrients. Vast quantities of nutrients and other pollutants are washed off the land and into the Great Lakes by rainfall. Nonpoint sources are major contributors of biological pathogens, nutrients, sediments, metals, and other toxic chemicals in the Great Lakes.

Nonpoint source pollution is diffuse. A suburban lawn can be a nonpoint source of water pollution. Farmlands, parking lots, streets, and construction sites are other nonpoint sources.

Eutrophication problems in Lake Erie, Lake Ontario, and in Saginaw Bay cannot be solved by point source controls alone. For example, the western basin of Lake Erie continues to be eutrophic despite improvements in point source controls. Eighty percent of the phosphorus entering the basin is from diffuse sources, mostly soils that have washed off agricultural lands during

Figure 8-2.—Simulated Total Phosphorus in Lake Michigan, Lake Ontario, and the Eastern Basin of Lake Erie, 1974-99.


Total Phosphorus (μg/L)
Lake Michigan
Objective Concentration = 7 μg/L
Lake Erie - Eastern Basin
Objective Concentration = 10 μg/L
Lake Ontario
Objective Concentration = 10 μg/L
1973 75 77 79 81 83 85 87 89 91 93 95 97 99
Year

Source: Great Lakes Water Quality Board, *1989 Report on Water Quality*, International Joint Commission, Windsor, Ontario (October 1989), page 78.

and after rain storms. The problem is visible in satellite photos of the western basin after a rain. Great clouds of sediment can be seen entering the Lake from the Maumee and Sandusky Rivers, which run through the rich agricultural lands of northwestern Ohio, and from the Detroit River, which picks up the sediments dumped in Lake St. Clair by the Thames River, which runs through southern Ontario's farm belt.[42]

In 1983 national, state, and provincial governments established ambitious goals for reducing nonpoint sources of phosphorus by 1990. Each of the Great Lakes states was given a target for reducing phosphorus loads. The 1990 reduction goals for Lake Ontario, Lake Erie, and Saginaw Bay are shown in Table 8-4, along with the actual reductions achieved by 1988.

Table 8-4.—U.S. Phosphorus Load Reduction Goals for 1990 in Lake Erie, Lake Ontario, and Saginaw Bay, as Compared to 1988 Reduction in Phosphorus Loads.

BODY OF WATER	PHOSPHORUS
	metric tons/year
Lake Erie:	
1990 Goal	1,700
1988 Reductions	330
Reduction Needed to Meet 1990 Goal	1,370
Lake Ontario:	
1990 Goal	235
1988 Reductions	106
Reduction Needed to Meet 1990 Goal	129
Saginaw Bay:	
1990 Goal	225
1988 Reductions	208
Reduction Needed to Meet 1990 Goal	17

Source: EPA Great Lakes National Program Office, *U.S. Progress in Implementing the Great Lakes Water Quality Agreement*, EPA, Chicago (1989), pages 4–5.

Progress among the states in reaching the targets for nonpoint nutrient control has been uneven. Indiana has reached its target, and New York and Michigan have made substantial progress. Ohio and Pennsylvania are behind schedule. Some portion of the reductions that have been in evidence in all the states may be attributable to the dry weather of 1988, which reduced river flows and erosion.

The Canadians are not doing much better. A recent study of Ontario agricultural counties reveals that many Canadian farmers are using fertilizers and phosphorus-based pesticides at

three times the recommended rates; moreover, only minimal use has been made of agricultural conservation practices that could reduce erosion.[43] Phosphorus levels in local streams, including the Thames River, violate water quality standards more or less all the time, even in dry weather. Cadmium in streams also exceeds standards 100 per cent of the time. Three samples out of 10 exceed the aquatic life standards for lead.

The story of nonpoint controls in the Great Lakes mirrors the nonpoint control situation nationwide. There is now widespread understanding and convincing evidence that nonpoint sources need to be controlled. A number of demonstration projects have established techniques and land management practices for controlling polluting runoff, especially on farms. New federal laws, including the Water Quality Act of 1987 and the "Sodbuster" amendments to national farm legislation, impose large new regulatory responsibilities on the states and the private sector. In addition, in the Great Lakes area the Canadian-American agreements of the last few years impose new international obligations to meet erosion control targets.

Many federal and state regulatory officials in the Great Lakes states believe that the new national programs for controlling nonpoint source pollution have not yet had a positive impact in the Great Lakes. The Environmental Protection Agency's most recent Phosphorus Reduction Report recommends a number of ways to improve existing programs.[44] For example, one method of reducing erosion is to maintain a filter strip of dense vegetation along the banks of streams. Programs to encourage such filter strips operate on a year-to-year basis, and they have not yet had a long-term impact on the Great Lakes. Similarly, restoration of wetland areas and better protection of existing wetlands are other steps that might reduce nonpoint pollution on a long-term basis.

Table 8-5 illustrates the importance of nonpoint sources to the total phosphorus budget of the Great Lakes. As can be seen from the numbers, nonpoint pollution is a major part of the phosphorus budget.

The nonpoint control effort in the Great Lakes region, as in the country as a whole, has focused on the agricultural sector. Agriculture is a major source of nutrient pollution. It is, however, by no means the only source. Stormwater from city streets, parking lots, lawns, construction sites, and landfills carries large

Table 8-5.—Estimated Industrial, Municipal, and Tributary Phosphorus Loading Data to the Great Lakes by Point and Nonpoint Attribution, 1986.

PHOSPHORUS SOURCE	LAKE SUPERIOR	LAKE MICHIGAN	LAKE HURON	LAKE ERIE	LAKE ONTARIO	ST. LAWRENCE RIVER
	metric tons/year					
POINT:						
Direct Industrial Discharge	81	60	23	38	29	14
Indirect Industrial Discharge	79	79	35	30	27	0
Direct Municipal Discharge	78	367	134	1,689	1,384	146
Indirect Municipal Discharge	60	488	305	724	365	27
Point Subtotal	298	995	496	2,481	1,805	188
NONPOINT:						
Tributary: Monitored	1,206	2,646	1,505	5,446	1,985	93
Adjustment for Unmonitored Area	1,064	881	803	1,753	652	90
Nonpoint Subtotal	2,269	3,527	2,308	7,199	2,637	182
Within-Lake Totals	2,567	4,522	2,805	9,680	4,441	370

Totals may not sum due to rounding.
Source: Great Lakes Water Quality Board, *1986 Report on Water Quality: Report to the IJC*, International Joint Commission, Windsor, Ontario (1987), page 36.

quantities of pollutants to the Great Lakes and their tributaries. Moreover, many sewage systems in the region carry sanitary wastes and stormwater in the same pipes. Each significant rainfall overloads the sewage treatment systems, which then discharge raw sanitary sewage and polluted stormwater.

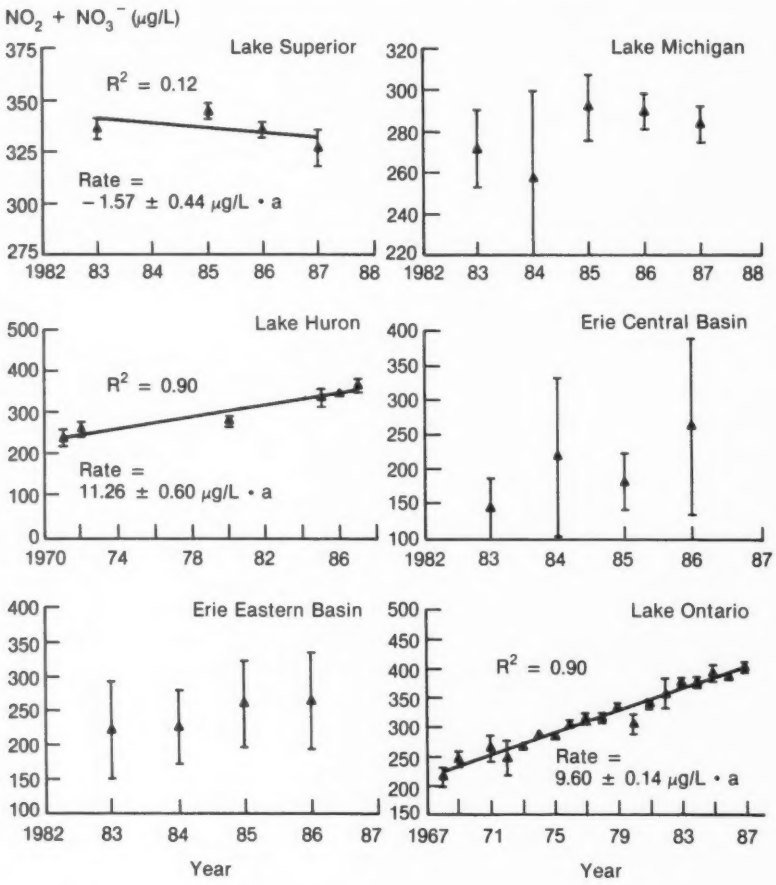
In general, while substantial progress has been made, an effective strategy for combating nonpoint pollution of North America's Great Lakes is not in place. Solving the problem will require action—coordinated action—by the International Joint Commission, the federal governments of the United States and Canada, and the state and provincial, and local governments. Changes in industrial and agricultural practices, waste management, and consumer habits all must contribute to solving the ecosystem-wide scourge.

Other Nutrients

The nutrient problem with perhaps the largest potential economic consequences is nitrogen. Nitrogen levels in the Great Lakes basin have been increasing steadily.[45] Nitrogen levels in

Lake Superior have quadrupled in the last 100 years.[46] Lake Ontario has experienced nitrogen increases of almost 10 μg/L per year for the past 20 years.[47] Some of those trends are illustrated in Figure 8-3. There are currently few controls on the substantial discharges of nitrogen compounds from sewage plants and industrial facilities. Nonpoint control efforts have been focused primarily on phosphorus.

Figure 8-3.—Nitrite + Nitrate Concentrations in the Great Lakes.



Source: International Joint Commission, *Third Biennial Report under the Great Lakes Water Qaulity Agreement of 1978*. IJC, Windsor, Ontario (1986), page 36.

The effects of rising nitrogen levels are not well understood. Nitrate and nitrite concentrations of 10 mg/L can render drinking water unpotable. Although nitrate levels in the Great Lakes as a whole are still too low to cause drinking water problems in the near term, scientists caution that water intakes should be monitored. Moreover, if the trends illustrated in Figure 8-3 continue, the largest source of potable water on the planet could be impaired.

A second, more immediate, and less understood risk is that rising nitrogen levels could cause subtle changes in the phytoplankton, thus setting off a chain reaction of the type that occurred 20 years ago. Thus far, no adverse impacts have yet been detected as a result of rising nitrogen levels.

Control of nitrogen discharges could cost substantially more than the billions already spent on phosphorus control, given conventional technologies. In its third biennial report, the International Joint Commission stated:

> *Governments may, in the near future, be compelled to address the question: After phosphorus, what? If other nutrients require control, significant financial resources may be required as they have been for phosphorus control and research since 1972. Unwise planning with respect to other nutrients may reduce the achievements of phosphorus control.*

Another troublesome nutrient is silica, one of the most common elements in the earth's crust. Silica is the building block of sand and many rocks. Yet this most common of elements seems to be in short supply in the Great Lakes. The most desirable microscopic creatures in the Lakes are diatoms, which are distinguished by their silica shells. The major source of the type of silica favored by the diatoms are the decaying bodies of other diatoms. Investigators now believe that the present mix of nutrients in the lakes causes these tiny creatures to use more silica than in the past. The net result is fewer, but larger, diatoms, which could stress all the creatures higher up the food chain.[48]

Toxics

Toxic chemicals are finding their way into the Great Lakes through many pathways. Despite existing regulations, industries and cities continue to discharge large amounts of toxic chemicals that end up in the Great Lakes. Over the last century, sediments on the bottom of the lakes have become reservoirs of toxic chemicals, which frequently leach into the lake water and circulate through the food chain. Runoff from city streets, highways, and farm fields carries heavy loads of toxic metals, petroleum-based products, pesticides, and other chemicals into the lakes. Many of the toxic chemicals emitted into the atmosphere by smokestacks and tail pipes around the world find their way into the Great Lakes. Groundwater contaminated by poorly designed or managed solid waste landfills is yet another route by which the Great Lakes are being degraded.

Point Sources

The Clean Water Act of 1972 imposed limits on industrial and municipal discharges of pollutants. For the most part, early regulations controlled so-called conventional pollutants, particularly oxygen-demanding material and suspended solids. Reducing the discharge of these materials also brought about a reduction of toxic discharges. For example, many toxins that adhere to the surfaces of suspended solids were kept out of the Great Lakes by conventional treatment techniques.

On the other hand, many toxins continued to enter waterways through factory and municipal effluent pipes. In 1987 Congress passed amendments to the Clean Water Act requiring a further racheting down of toxic material discharges.

At about the same time, municipal governments, under pressure from state and federal regulators, began to implement industrial pretreatment programs. Industries that discharged their effluents to public sewers were required to remove any toxics that could pass through the municipal sewage treatment plants, damage the plants, imperil workers, or cause the residual sludge produced in the plants to become hazardous. By 1989 more than 95 percent of U.S. Great Lakes municipalities had instituted state-approved pretreatment programs.[49]

Those steps further reduced toxic discharges from effluent pipes, but they did not end them. The pulp and paper industry, for example, which has made progress in reducing conventional pollutants, continues to be a significant source of persistent toxic materials, including dioxins, in the waters of the Great Lakes basin. The use of chlorine as a bleaching agent in the production of white paper results in discharges of 10,000 tons per year of organochlorines into the lakes. A significant fraction of this family of toxic chemicals tends to bioaccumulate. Several studies have indicated that current bleach plant effluents "might have large-scale, long-range environmental effects."[50]

Despite the new pretreatment programs, U.S. and Canadian municipalities continue to discharge large amounts of toxic metals, especially chromium, lead, copper, and zinc into the Great Lakes.

Nonpoint Sources

The total amount of toxics entering the Great Lakes waterways from stormwater and combined sewer overflows can only be estimated. In the Detroit area, which is one of the most urbanized and industrialized regions in the basin, most of the existing information is based on studies at least 10 years old. However, those studies have generated environmental concerns. For example, combined sewage overflows from Detroit may be responsible for 96 percent of the mercury, 33 percent of total PCBs, 25 percent of the cadmium, 29 percent of the chromium, and 32 percent of the lead entering the Detroit River each year.[51]

Groundwater

Most of the streams that feed the Great Lakes flow even in the driest weather, because they are fed by underground aquifers. The aquifers, in their natural state, are sources of pure water. However, the aquifers in heavily industrialized and urbanized areas often are contaminated with industrial chemicals. Farmlands leach herbicides, pesticides, and nutrients, especially nitrogen, into the aquifers. The chemicals then find their way into tributaries and thence into the Great Lakes. Moreover, along the Niagara River and the St. Clair River in the Sarnia

region of Ontario, inadequately controlled hazardous waste landfills may be having severe impacts on surface water via groundwater.[52]

Neither the United States nor Canada has mapped the routes of contamination through groundwater, although the EPA has begun efforts in this area. Such information is needed to formulate a strategic approach to this problem and to provide benchmarks for measuring progress in the future.

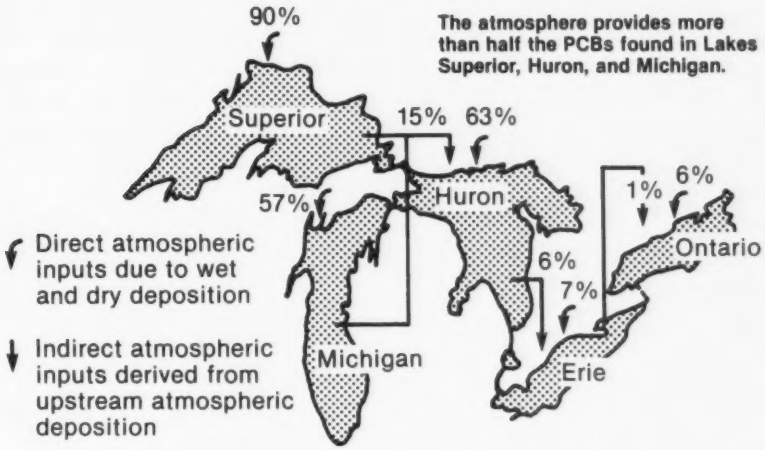
Airborne Toxics

Isle Royale, in the middle of Lake Superior, is 50 km from the nearest city, Thunder Bay, Ontario. Since 1940 the island has been a national park and has been relatively untouched by human activity. In the middle of the island is Siskiwit Lake, a spring and rain-fed body of water that receives no inflow from Lake Superior. Siskiwit Lake can only be reached by a backpack trail. If any portion of the Great Lakes basin can be described as pristine, it is Siskiwit Lake on Isle Royale.

Yet, for the last 15 years, scientists have been discovering chemicals usually associated with intense industrial and agricultural activity in the tissues of fish caught in Siskiwit Lake. Some of the chemicals are not known to have been used to any significant extent anywhere in the Great Lakes basin. Toxaphene, for example, an agricultural chemical sprayed on cotton fields, is not in use in any of the Great Lakes states. Investigations of Siskiwit fish suggest that substances like toxaphene arrived by air, often from a great distance.[53]

If the Siskiwit studies proved the link between the atmosphere and water quality, subsequent investigations demonstrated that the phenomenon is not confined to Isle Royale. Indeed, the evidence is convincing that all the Great Lakes are receiving airborne debris, much of it toxic, from very great distances. Some of the DDT used in South America to combat malaria finds its way into the lakes. As much as 90 percent of the PCBs in Lake Superior come from the atmosphere. Figure 8-4 quantifies the percentages of PCBs that are deposited out of the air into the other lakes. The percentages are lower in the lower lakes because of the large amounts of PCBs that are deposited there from effluent pipes, land runoff, contaminated groundwater, and contaminated sediments.

Figure 8-4.—Concentrations of PCBs in the Great Lakes.



Source: Strachan, W.M., and S.J. Eisenreich, *Mass Balancing of Toxic Chemicals in the Great Lakes: The Role of Atmsopheric Deposition*, International Joint Commission, Windsor, Ontario (1988).

America's greatest surface water resource is uniquely susceptible to global air pollutants. The Great Lakes are ideal receivers of airborne toxics because of their enormous surface area. Once chemicals reach the lakes, they tend to stay for many years, sometimes for centuries. Thus it is clearly in the interest of the two countries with the largest freshwater lake system in the world to work together to limit toxic air pollution.

Contaminated Sediments

For the last 150 years, soils, silts, clays, sands, organic materials, and debris have been washing into the Great Lakes and their tributaries. The materials, which form a bottom sediment, are rich in nutrients and often are contaminated with hazardous chemicals. The sediments that retain the greatest amount of toxic contaminants tend to be fine clays—those composed of the smallest particles and with the largest surface area per unit volume.

As much as 90 percent of the space in the top layers of bottom sediments is water.[54] Many of the toxic chemicals move from the clay particles to the water and back again. Contaminated sediments have significant effects on so-called benthic (bottom-dwelling) organisms and, through them, the entire Great Lakes ecosystem. For example, the mayfly spends its larval stage in the bottom mud and its adulthood on the water surface, where it provides food for many other creatures. An absence of mayflies on the surface is a symptom of contaminated sediments on the bottom.

Many of the benthic organisms disturb the bottom sediments through burrowing and digging, thereby causing pollutants to be resuspended in the water. Large ships, storms, and water mixing caused by seasonal changes in temperature have the same effect. In general, however, the processes and rates by which contaminants move from sediment to water to atmosphere and back again through the biota are not well understood.

The U.S. Army Corps of Engineers is responsible for projects intended to keep the channels of navigation in the Great Lakes and tributaries open to shipping. Given the high rates of sedimentation, the Corps is required to dredge the channels frequently. Disposing of the dredged material always has been a problem, and today that problem is aggravated by the presence of toxic materials. Dredging itself may cause contaminants to be resuspended in the water, and disposing of the dredged sediment can cause further environmental problems.

In the 1960s and 1970s the Corps built a number of confined disposal facilities (CDFs) to hold the dredged materials. CDFs, which are surrounded by stone dikes, often are built in shallow waters with the natural shoreline serving as one boundary of the facility. Sometimes CDFs are built as islands, where partially dewatered sediments are deposited. About 30 such facilities are now in the Great Lakes. While they have a number of advantages —reduced land costs and location near sediment sources and away from businesses and residences—they have a number of environmental drawbacks. CDFs are not secure hazardous waste facilities. In fact, they are designed to leak. They are very attractive to insects and birds, which may take up and spread toxic chemicals contained in the dredged sediments.

The Corps of Engineers is being pressured by public opinion and its own concern about ecology to explore more expensive ways of permanently entombing or otherwise destroying the dangerous sediments it is dredging up from navigation channels. The most cost-effective solution is, of course, to prevent the contamination of sediments and to reduce erosion that is pouring sediments into the navigation channels. (For a more complete discussion of pollution prevention, see Chapter 6 of this report.)

Many of the people most concerned about the Corps' navigational dredging advocate an expansion of dredging activity to clean up some of the most contaminated sediments in the Great Lakes ecosystem.[55] The Clean Water Act of 1972 gave the Corps authority to extend its dredging beyond that required for navigation and to dredge to abate pollution. As a practical matter, however, primary responsibility for cleaning up contaminated sediments in the areas of concern remains with state and local governments and the private sector.

Progress Assessment

Toxic chemicals are entering the Great Lakes ecosystem from the sky above and from the groundwater below. Farms and factories, streets and sewage plants all contribute to the problem. Many of the chemicals of concern cause environmental degradation in minute concentrations. Monitoring, which is expensive and complex, has begun only recently for some chemicals, and the significance of some types of measurements, especially measurements of total PCBs, is in doubt. Other long-standing monitoring protocols have been interrupted or curtailed in recent years because of financial constraints.[56] In short, long-term reliable data are rare.

Yet between 1969 and 1972 Canada and the United States banned or restricted the use and production of heptachlor, dieldrin, DDT, PCBs, and mercury. In 1976 mirex production ceased. Those actions caused the concentrations of those chemicals in fish and fish-eating birds to decline significantly. During the decade of the 1980s, the data suggest continued but slower rates of improvement with regard to some of the banned chemicals, despite the fact that evidence indicates some of those chemicals are still being discharged into the lakes, especially Lake

Ontario. In some cases, chemical concentrations in fish are actually on the rise. PCBs in fish from all of the Great Lakes still exceed the safety levels agreed upon by Canada and the United States, and fish consumption advisories for PCBs, mirex, and mercury are still common.[57]

In 1989 the Water Quality Board of the IJC summarized trends in toxic contamination of eggs collected from herring gull colonies in a report that stated:

- **DDE.** Concentrations in eggs collected from colonies throughout the Great Lakes in 1988 increased over 1987 levels. However, compared to DDE levels in herring gull eggs at the beginning of the decade, levels in 1988 were 48 percent lower in two Lake Huron bird colonies.

- **Dieldrin.** Concentrations for 1988 increased in 10 of 12 colonies over 1987 levels. However, no statistically significant difference was observed between 1980 and 1988 values.

- **Mirex.** Compared to 1987 concentrations, 1988 levels increased in 4 of 12 colonies, decreased in 3, and remained unchanged in 5. Since 1980, mirex levels have decreased in 11 of 12 colonies.

- **Hexachlorobenzene (HCB).** In 1988 concentrations increased from 1987 levels in 8 of 12 colonies. However, since the beginning of the decade, there has been a 50-percent decrease in 3 Lake Huron colonies.

- **PCBs.** In 1988 concentrations increased from 1987 levels in 8 of 12 colonies. However, since 1980 total PCBs have decreased in all 12 colonies, and levels in 1988 were 54 percent lower than in 1980 for 3 Lake Huron colonies.

- **2,3,7,8-TCDD.** Unlike most compounds, levels of 2,3,7,8-TCDD decreased in 1988 compared to 1987. Since 1980 2,3,7,8-TCDD levels appear to have decreased in the reporting colonies.[58]

Thus it appears that the only chemicals to have declined significantly in the Great Lakes ecosystem are those whose production and use have been prohibited outright or severely restricted.

Lake-by-Lake Report

In its 1988 Report to Congress, EPA provided a lake-by-lake progress report on the Great Lakes cleanup effort. The following summary is taken primarily from that document.[59]

■ **Lake Superior**. Closer to its pristine state than any of the others, Lake Superior is oligotrophic; that is, overall productivity of algae is very low. Diatoms and other desirable species are dominant. Oxygen levels in the depths of the lake are adequate to support life year round.[60]

Due to its vast size, the geological characteristics of the surrounding land, and the general sparseness of human settlement, adherence to sewage treatment discharge standards may be enough to maintain Lake Superior's nutrient balance. Yet nearly 500 metric tons of phosphorus enter Lake Superior from the atmosphere each year.

Lake Superior's size makes it an easy target for airborne pollutants from around the world.[61] PCBs from the air have caused the states to issue public health advisories on consumption of lake trout and walleye. Lake Superior is the only place where native lake trout still thrive without human intervention.

The International Joint Commission has designated seven areas of Lake Superior as areas of concern. An area of concern (AOC) is a region that suffers from a particularly severe combination of toxic and other problems. The three U.S. areas of concern are:

- ***St. Louis River/Bay.*** Sediments in St. Louis Bay, at the western tip of the lake, are moderately to heavily polluted with arsenic, chromium, and copper. Some sediments also are contaminated by lead and mercury.

- ***Torch Lake.*** **Copper levels in the water are 6-10 times higher than the IJC target levels. Sediments are also contaminated with copper. The population of larger invertebrates is sparse, and walleye and sauger exhibit a variety of tumors. State agencies advise against eating walleye and sauger caught in Torch Lake, no matter how large or small.**

- ***Deer Lake–Carp Creek/River.*** **Sediments and fish are contaminated by mercury. No bald eagle offspring have been produced from nesting areas. Health advisories restrict consumption of all species of fish.**

■ **Lake Huron.** Also in fairly good condition, Lake Huron has a healthy mix of phytoplankton typical of an oligotrophic lake.[62] Concentrations of dieldrin and DDT in Lake Huron fish are within safety tolerances, but the concentrations have not changed since 1979. PCB levels in fish exceed safety limits and show no signs of declining. Consumption of lake trout, rainbow trout, and brown trout may be unsafe.

Of the four AOCs in Lake Huron, only one is within the United States. Saginaw River/Bay suffers from most of the pollution problems caused by an industrial society, including severe eutrophication. Shore areas immediately to the south and north of Saginaw Bay are close to a mesotrophic condition; that is, they are somewhere between eutrophic and oligotrophic. While direct discharges of phosphorus have declined, the concentrations of phosphorus in the open waters of Lake Huron have not declined since 1976.[63]

Contaminants in the water of Saginaw Bay include metals, PCBs, and phenols. Bay sediments also are contaminated with metals and PCBs. A health advisory recommends no consumption of carp and catfish, while consumption of lake trout, brown trout, and rainbow trout is restricted. Fish-eating bird populations also are being affected by contaminants, as shown by reproductive failure and increased incidence of cross-beak syndrome.

■ **Lake Michigan.** The only Great Lake completely within the United States exhibits all the trophic conditions. The southern end of Green Bay, at the mouth of the Fox River in Wisconsin, is

unquestionably eutrophic. The same is true of areas near Milwaukee. The southern tip of Lake Michigan, which is strongly influenced by the Grand Calumet River and the Indiana Harbor Canal, is also eutrophic. Most of the southern and eastern shores of Lake Michigan are between oligotrophic and mesotrophic. The central waters are oligotrophic.

PCB and DDT concentrations in Lake Michigan lake trout appear to be gradually declining, but they remain above the safe limits. PCB concentrations are about 40 times the target amounts. DDT concentrations are twice as high as allowed tolerances, and dieldrin concentrations hover just below allowable levels.

The public has been advised not to eat any carp, catfish, or very large lake trout, chinook salmon, or brown trout caught in Lake Michigan. Restrictions have been placed on other fish as well.

The IJC has identified 10 areas of concern in Lake Michigan:

- ***Manistique River.*** The lower river and harbor have elevated levels of PCBs and lead. Harbor sediments contain cadmium, lead, PCBs, and zinc. The bottom of the harbor is dominated by pollution-tolerant species.

- ***Menominee River.*** Water in the lower river is contaminated with arsenic. Sediments are moderately to heavily contaminated by arsenic, mercury, and PCBs. Local fish exhibit tumors, and river water is toxic to certain aquatic invertebrate larvae.

- ***Fox River and Southern Green Bay.*** Over 100 toxic substances, including 37 on the EPA priority pollutant list, and 11 different resins and fatty acids have been found in discharges to the lower Fox River. Sediments in the lower river are heavily polluted with lead, oil and grease, mercury, PCBs, zinc, and DDT. Fish tumors are very common, and consumption is restricted for 10 species. Cormorants are having trouble reproducing, and herring gulls suffer from thyroid problems. Bacteria densities periodically put the area off limits for swimming. The lower bay is highly eutrophic.

- ***Sheboygan Harbor.*** PCB levels in the water and the sediment are very high. Pollution-tolerant species predominate.

- ***Milwaukee Estuary.*** Open water and sediments are heavily polluted with cadmium, chromium, copper, lead, oil and grease, PCBs, and zinc. Chlordane and DDT are also present. Pollution-tolerant species dominate the food chain. Combined sewage overflows during rainfall cause very high bacteria count at local beaches. The harbor is eutrophic, and the consumption of numerous fish species has been restricted.

- ***Waukegan Harbor.*** In portions of this harbor, concentrations of PCBs in the sediment are as high as 50 parts per 100.

- ***Grand Calumet/Indiana Harbor.*** Water quality standards are exceeded for copper, lead, selenium, iron, zinc, ammonia, and phenols. Sediments are contaminated with chromium, lead, oil and grease, PCBs, and zinc. Fish suffer from tumors and a high incidence of fin rot. No fish caught in this area should be eaten, and bacterial counts are high.

- ***Kalamazoo River.*** High PCB levels have been found in the water and sediment. Consumption of all fish is restricted. Phosphorus levels downstream of Kalamazoo are high.

- ***Muskegon Lake.*** Some shoreline sediments are contaminated with cadmium, copper, lead, mercury, zinc, and pyrene. Excess nutrients cause algal blooms.

- ***White Lake.*** This lake is polluted through groundwater. Pollutants include chloroform, trichloroethylene, carbon tetrachloride, and perchloroethylene. Sediments are contaminated with chromium.

■ **Lake Erie.** The first of the lakes to succumb to severe overenrichment, Lake Erie was also the first to show signs of a strong recovery. Waters move through Lake Erie more rapidly than through the other lakes. It takes 2.6 years for the volume of water in Lake Erie to pour over Niagara Falls and through the Welland Canal into Lake Ontario. In contrast, Lake Superior's average water residence time is 191 years. Thus Erie is likely to respond more quickly to reductions in pollution than the other lakes.

Phosphorus discharges into Lake Erie have declined from a high of 28,000 metric tons per year of phosphorus discharges in the 1960s to a little less than 11,200 tons today.[64] Most of this reduction was achieved by cutting back on the phosphorus discharged by municipal sewage treatment plants. Legislated restrictions on phosphate detergents in six of the Great Lakes states and the Province of Ontario also helped reduce the load.[65]

Lake Erie's improvements are dramatic. However, during summer stratification, the deep waters in the center of the lake still lose all or most of their oxygen. Most of the near-shore waters are eutrophic or mesotrophic, and the shallow waters in the western end of the lake continue to be overenriched. The 80-90 percent reduction in phosphorus discharges achieved through regulation of municipal sewage plants and industries has not been adequate to restore Lake Erie's chemical balance.

As with the other lakes, the largest toxic problem in Lake Erie is PCBs. Concentrations of PCBs in walleye exceed objectives contained in the Great Lakes Water Quality Agreement by as much as five times. They are, however, four times lower than levels set by the FDA to protect human health.

There are seven areas of concern within the U.S. boundaries of Lake Erie and its upstream channels with Lake Huron:

- ***Clinton River.*** Sediments are contaminated with oil and grease. Fecal coliform and phosphorus both exceed acceptable levels.

- ***Rouge River.*** Water and sediments are polluted with metals, PCBs, HCB, dibenzofurans, and polynuclear aromatic hydrocarbons (PAHs). Fish kills occur regularly in the summer. Combined sewer overflows contaminate the river with bacteria.

- ***Raisin River.*** Water and sediments are contaminated with metals and PCBs. Invertebrates have died off in the vicinity of Monroe Harbor. Combined sewer overflows occur regularly during wet weather.

- ***Maumee River.*** Ammonia, arsenic, lead, copper, zinc, cadmium, iron, and mercury all exceed Ohio's water quality standards. Sediments are contaminated with metals and have been found toxic to minnows and invertebrates.

- ***Black River.*** Ohio water quality standards are violated for ammonia, iron, lead, phenol, cyanide, cadmium, copper, and zinc. Sediments are contaminated with oil and grease, metals, and PAHs. The bottom environment is severely degraded. Fecal coliform exceeds standards, and no fish from the Black River should be eaten.

- ***Cuyahoga River.*** Toxics in the river include cyanide, metals, ammonia, and phenols. Sediments are polluted with metals, oil and grease, and moderate levels of PCBs, DDT, PAHs, and phthalates. The bottom environment is degraded, and fecal coliform bacteria frequently exceed health standards. Despite such problems, the Cuyahoga is now in much better condition than it was 20 years ago.

- ***Ashtabula River.*** Zinc, cadmium, and mercury exceed Ohio's water quality standards. Sediments are highly polluted. River water is acutely toxic to *Daphnia*, a kind of water flea that lives in clean streams. No fish from the Ashtabula should be eaten.

■ **Lake Ontario.** Some near-shore waters of Lake Ontario are between eutrophic and mesotrophic, despite substantial reductions in phosphorus loadings. Because it is located at the end of the Great Lakes chain, Lake Ontario receives toxics and nutrients from all the other lakes. Pollution concentrations in the open waters of the lake are generally high compared to those found in the open waters of the other lakes. Yet the rate of eutrophication appears to be declining in response to phosphorus controls.

Progress is uneven, however. Phosphorus loadings in the Bay of Quinte, a sheltered portion of Lake Ontario, were cut in half in 1977, and a year later phytoplankton biomass declined sharply. However, by 1984-85 the biomass of phytoplankton was close to that of the pre-phosphorus control period, despite continued low loadings.[66]

Although the United States and Canada have agreed to phosphorus targets for Lake Ontario, scientists are still uncertain about the appropriate balance of nutrients in the lake. The most recent loading estimate for Lake Ontario is nearing the target load of 7,000 metric tons per year.

PCB levels in Lake Ontario fish are decreasing, even though they still exceed acceptable levels by a factor of 10. DDT concentrations in fish have stabilized at just above the safe limits. Dieldrin concentrations are declining. The ambiguity of the toxic situation in Lake Ontario is reflected in the public health advisory not to consume more than one meal a month of white perch, coho salmon (under 21 inches), or rainbow trout (under 18 inches). Consumption of a number of other fish is considered unsafe.

There are four areas of concern within the Lake Ontario Basin:

- ***Buffalo River.*** Water quality standards are exceeded for metals, dieldrin, benzene hexachloride (BHC), and chlordane. Sediments are polluted with oil and grease, iron, and mercury. Pollution-tolerant species dominate the deeper waters.

- ***Eighteen Mile Creek/Olcott Harbor.*** Trichlorofluoromethane pollutes the water, along with cadmium, copper, lead, nickel, DDT, and dieldrin. Sediments at the mouth of the creek are moderately to heavily polluted with metals.

- ***Rochester Embayment.*** Ammonia levels exceed New York state objectives. Harbor sediments contain excessive amounts of arsenic, copper, cyanide, nickel, and zinc. Combined sewer overflows keep phosphorus levels high.

- ***Oswego River.*** Water is contaminated with metals, chloroform, and ammonia. Sediments are moderately to severely polluted with arsenic, copper, and manganese. Salt concentrations have altered the composition of river phytoplankton.

■ **Connecting Channels.** The St. Mary's River, St. Clair River, Lake St. Clair, the Detroit River, and the Niagara River, known collectively as the connecting channels, are the major links between each of the Great Lakes. The St. Lawrence River is the major outflow of the Great Lakes system to the Gulf of St. Lawrence and ultimately the Atlantic Ocean. The St. Lawrence and every one of the connecting channels except Lake St. Clair has been designated an area of concern. They suffer from all the ills that affect the Great Lakes themselves. The major sources of problems are the old urban-industrial complexes on each of these rivers.

Planning for Clean Water

Pursuant to the Water Quality Agreement between the United States and Canada, federal, state, provincial, and municipal governments in the Great Lakes region are engaged to an unprecedented degree in water quality planning. Three types of planning are going forward. Remedial action plans (RAPs) are being developed to restore beneficial uses in each area of concern. Lakewide management plans (LMPs) are intended to correct pollution problems in the open waters of the lakes. Plans for Point Source Impact Zones are intended to identify and minimize the immediate effects of discharges from particular factories and sewage plants.

The Point Source Impact Zones are the newest manifestation of the old problem of mixing zones. Some large municipalities and industries contend that they need a mixing zone adjacent to their discharge pipes in which water quality standards are considerably less stringent than in the stream or lake as a whole. That

zone is needed, the argument goes, to permit dispersion of pollutants to acceptable levels, and to avoid huge expenditures in additional pollution controls without overall benefit to the ecosystem.

State governments have established different and sometimes conflicting rules for mixing zones. Critics of the process believe that Point Source Impact Zones should be outlawed or curtailed. The IJC encourages a negotiating process for each of the major mixing zones in the basin to minimize environmental impacts.

The object of Lakewide Management Planning is to arrive at target loadings for each of the critical pollutants affecting the whole ecosystem of the lakes. LMPs led the International Joint Commission and the national governments to establish numerical goals for the total amount of phosphorus that should be permitted to enter each of the lakes. Thus the goal for Lake Erie is to reduce phosphorus loadings by another 1,700 metric tons. The LMP process also involves an allocation or rationing of discharges among the various jurisdictions, and an identification of the means to achieve the goal. In the case of Lake Erie, the original means was to impose strict discharge standards on municipal and industrial polluters. In the future, the means to attain the overall phosphorus goal involves new controls on nonpoint sources. This type of planning has proven remarkably successful in combating eutrophication.

The lakewide planning process is intended to continue the nutrient control program and to establish similar goals, allocations, and methods for reducing and eventually eliminating toxic chemicals from the ecosystem. Yet planning for the reduction and elimination of toxic chemicals is much more complex and expensive than nutrient planning. The type of planning that is likely to have the most immediate impact on the average resident of the region, and the one that is likely to be most costly, is remedial action planning for restoration of the areas of concern, the most polluted areas in the lake region. Table 8-6 summarizes water quality problems in each of the areas of concern, and Figure 8-5 shows the geographical location of those AOCs.

The International Joint Commission has called on the state and provincial governments, municipal governments, and U.S. and Canadian federal agencies to develop and implement remedial action plans (RAPs) for each of the areas of concern.

Table 8-6.—Water Quality Problems Identified in Areas of Concern of the Great Lakes Basin, 1987.

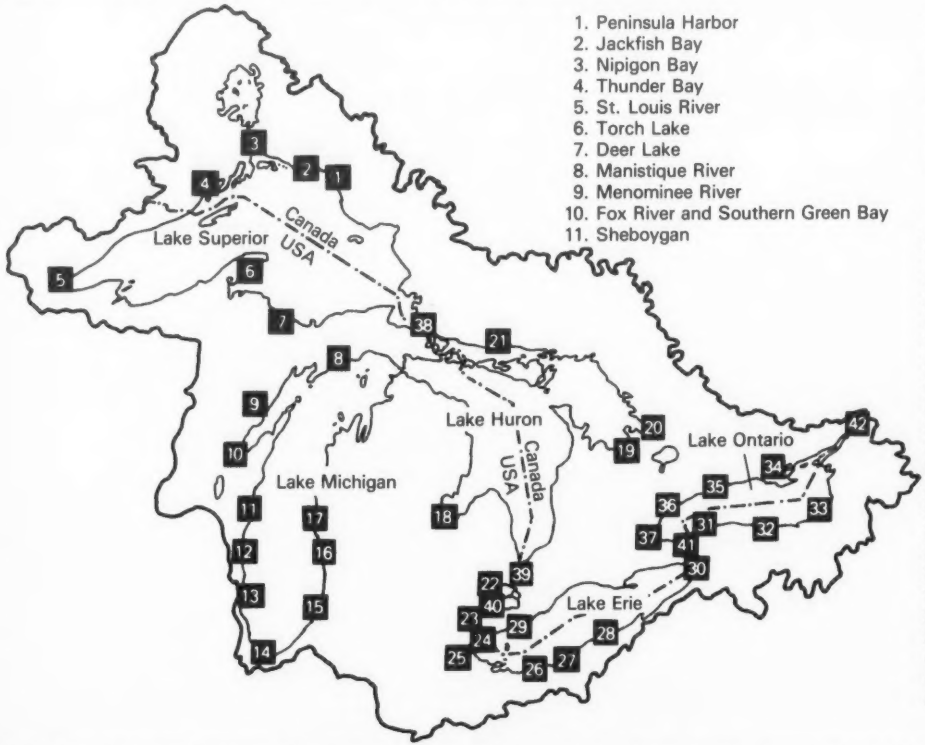
AREAS OF CONCERN	TOXICS IN WATER	TOXICS IN SEDIMENTS	HEALTH ADVISORIES ON FISH	FISH TUMORS*	IMPACTED BIOLOGICAL COMMUNITY	ELEVATED BACTERIA LEVELS	ELEVATED PHOSPHORUS LEVELS	DISSOLVED OXYGEN DEPLETION
Lake Superior								
Peninsula Harbor	●	●	●	N/D	●	X	●	X
Jackfish Bay	●	●	●	N/D	●	●	X	●
Nipigon Bay	●	●	●	N/D	●	●	X	X
Thunder Bay	●	●	●	●	●	●	●	●
St. Louis River/Bay	●	●	●	N/D	●	X	X	X
Torch Lake	●	●	●	●	●	X	X	X
Deer Lake-Carp Creek/River	X	●	●	N/D	●	X	●	●
Lake Michigan								
Manistique River	●	●	●	N/D	●	X	X	X
Menominee River	●	●	●	●	●	X	X	X
Fox River/S. Green Bay	●	●	●	●	●	●	●	●
Sheboygan Harbor	●	●	●	N/D	●	X	X	X
Milwaukee Estuary	●	●	●	N/D	●	●	●	●
Waukegan Harbor	●	●	●	N/D	●	X	X	X
Grand Calumet/Indiana Harbor	●	●	●	N/D	●	●	●	●
Kalamazoo River	●	●	●	N/D	●	●	●	●
Muskegon Lake	●	●	●	N/D	●	X	●	●
White Lake	●	●	●	N/D	●	X	X	X
Lake Huron								
Saginaw River/Bay	●	●	●	X	●	●	●	●
Collingwood Harbour	X	●	●	N/D	●	●	●	X
Penetang Bay to Sturgeon Bay	X	X	●	N/D	●	X	●	X
Spanish River	X	●	●	N/D	●	X	●	X

Lake Erie								
Clinton River	X	●	X	N/D	●	●	●	●
Rouge River	●	●	●	●	●	●	●	●
Raisin River	●	●	●	●	●	●	●	●
Maumee River	●	●	X	N/D	●	●	●	●
Black River	●	●	●	●	●	●	●	●
Cuyahoga River	●	●	X	●	●	●	●	●
Ashtabula River	●	●	●	N/D	●	●	●	●
Wheatley Harbour	X	●	●	N/D	●	●	●	●
Lake Ontario								
Buffalo River	●	●	●	●	●	●	●	●
Eighteen Mile Creek Olcott H.	●	●	●	N/D	●	X	X	X
Rochester Embayment	●	●	●	N/D	●	●	●	X
Oswego River	●	●	●	N/D	●	●	●	X
Bay of Quinte	●	●	●	X	●	●	●	●
Port Hope	●	●	●	X	●	X	●	●
Toronto Waterfront	●	●	●	●	●	●	●	X
Hamilton Harbour	●	●	●	●	●	●	●	●
Connecting Channels								
St. Mary's River	●	●	●	●	●	●	●	X
St. Clair River	●	●	●	X	●	●	●	X
Detroit River	●	●	●	●	●	●	●	X
Niagara River	●	●	●	●	●	●	●	X
St. Lawrence River	●	●	●	X	●	●	●	X

*In many cases, where fish tumors have been found, further work is warranted to determine the extent of the problem and the causative factor. In other cases, fish tumors have been directly lined to contamination by polynuclear aromatic hydrocarbons.

● **Problem exists** **X Problem not evident** **N/D No data available**

Figure 8-5. Areas of Concern in the Great Lakes Basin, 1989.



1. Peninsula Harbor
2. Jackfish Bay
3. Nipigon Bay
4. Thunder Bay
5. St. Louis River
6. Torch Lake
7. Deer Lake
8. Manistique River
9. Menominee River
10. Fox River and Southern Green Bay
11. Sheboygan
12. Milwaukee Estuary
13. Waukegan Harbor
14. Grand Calumet River and Indiana Harbor Ship Canal
15. Kalamazoo River
16. Muskegon Lake
17. White Lake, Montague
18. Saginaw River System and Saginaw Bay
19. Collingwood Harbor
20. **Penetang Bay to Sturgeon Bay**
21. Spanish River
22. Clinton River
23. Rouge River
24. Raisin River
25. Maumee River
26. Black River
27. Cuyahoga River
28. Ashtabula River
29. Wheatley
30. Buffalo River
31. Eighteen Mile Creek
32. Rochester
33. Oswego River
34. **Bay of Quinte**
35. Port Hope
36. Toronto
37. Hamilton Harbor
38. St. Mary's River
39. St. Clair River
40. Detroit River
41. Niagara River
42. St. Lawrence River

Source: Great Lakes Water Quality Board, *1987 Report on Great Lakes Water Quality*, International Joint Commission, Windsor, Ontario (March 1989).

The RAPs are to embody a "comprehensive, ecosystem approach to restoring and protecting beneficial uses." Thus, plans that address only one aspect of the problem are by definition inadequate.

Similarly, the focus of the RAP is beneficial use. That is, while numbers and standards are important, the real measure of success is whether people can swim where swimming was previously banned, whether fish and wildlife are returning to areas where they had been forced out or died out, whether in fact the real benefits of clean water are being restored.

Very few environmental regulations are written to protect entire ecosystems. In fact, most regulations have a very narrow focus. For example, uniform national standards often dictate the type of technological approach all members of a particular industry must take. Financial aid programs often define what kinds of pollution control expenditures are eligible for aid and what type are ineligible. Pollution is regulated on a pollutant-by-pollutant basis, for the most part without regard to their interrelationships. Air pollution and water pollution usually are regulated through different parts of state and federal governments. Because existing laws, financing mechanisms, and institutions often have not addressed the problem of restoring whole ecosystems, the participants in the RAP process are in a sense charged with inventing a new future. Among the key strategies that have begun to emerge are waste minimization, source reduction, remediation of contaminated sediments, nonpoint source control, and combined sewer overflow programs. Such programs typically have not been emphasized in previous regulatory efforts. Remedial action plans are a means to assess appropriateness on a case-by-case basis, to reach consensus on a technical approach, and to identify or create funding sources for actual implementation.

Public participation is a critical element in both remedial action plans and in lakewide management planning. Local industries, municipalities, citizens groups, and other participants are the principle "stakeholders", as their interests are linked to the fate of the Great Lakes ecosystem. Consensus among the various stakeholders is essential to the achievement of the policy and behavioral changes necessary for the restoration of beneficial uses.

The RAP process represents a significant shift of initiative from the centralized national governments to the local arena. Through a cooperative consultation process, local industries, governments, and citizens are setting environmental goals and helping select appropriate remedial actions to achieve those goals.[67] The national governments retain their authority to approve or disapprove final plans, and they are often key actors in implementing the plans.

By the end of 1989 draft plans had been produced for 8 of the 42 areas of concern. Public advisory committees or stakeholder groups had been assembled in 32 areas. A number of interjurisdictional agreements had been made. For example, 48 communities as well as state and federal agencies reached agreement and funded $310 million of sewer improvements along the Rouge River, Michigan; Michigan and Ontario have agreed to cooperate on joint RAPs for the St. Mary's, St. Clair, and Detroit Rivers; and New York and Ontario are developing RAPs for the Niagara and St. Lawrence Rivers.

In Waukegan Harbor, the corporation responsible for dumping PCBs has agreed to dredge the harbor and incinerate the PCBs. Steel companies at Hamilton Harbour, Ontario, chemical companies along the St. Clair River, Ontario, and paper mills along the Fox River, Wisconsin, have been encouraged to cut back on pollutants at the source. A number of other useful steps, especially in connection with defining problems, have resulted from the RAP process.

For the most part, however, the planning process has yet to achieve measurable results. Problems that have been brewing since the beginning of the industrial revolution in America cannot be solved quickly. In the case of the RAPs, the key issues are ones that 20 years of progressively more restrictive environmental legislation and $11 billion of public investment have left unresolved.

The cost of implementing the preliminary plans that have been developed is still unknown. One plan, for example, places the cost of remediation between $60 million and $600 million. And even if more precise financial information were available, it is still uncertain where the money would come from.

But by far the most significant development to date has been the increased level of public awareness and concern about the problems of the Great Lakes, especially the toxic problems, and the solid progress that has been made controlling eutrophication. The main unanswered question of the Great Lakes in 1989 was whether that progress can be continued and, in the case of toxic chemical pollution, duplicated.

Ecosystem and Economy

One aspect of the ecosystem approach is the linking of environmental protection to economic development and social concerns. In the words of the Brundtland Commission, established in 1983 by the United Nations to devise global strategies for sustainable development: "[T]he environment does not exist as a sphere separate from human actions, ambitions and needs, and attempts to defend it in isolation from human concerns have given the very word environment a connotation of naivety." In the Great Lakes, too, the byword is sustainable development, and the goal is to discover the link between water quality and human prosperity.

The periods of greatest environmental degradation of the Great Lakes appear to overlap with periods of regional economic decline. As Lake Erie was dying, the region became known in some quarters as the "rust bowl." A similar association can be seen in eastern Europe, in an extreme form. East Germany, Poland, Hungary, Romania, and the other industrial societies of Eastern Europe are beset with some of the world's worst environmental problems. The two systems—economic and environmental—seemed to be locked together in a web of causes and effects.

Conversely, environmental recovery goes hand in hand with economic resurgence. The active stance of the Great Lakes governors on behalf of environmental quality, the large investment in sewage and waste management infrastructure over the last 20 years, the revival of urban waterfronts, and similar events are indicative of a growing prosperity. Certainly, future improvements

in water quality of the Great Lakes will require modernization of Great Lakes industry, improvements in farming practices, restructuring of urban drainage and waste management systems, restoration of lake bottoms, wetlands, and other habitats, expansion of recreational facilities, a new ethic of waste avoidance and energy efficiency, and large investments in physical and human capital. These steps are not incompatible with economic development; they are essential elements of it.

Conclusion

The border between the United States and Canada, one-third of which runs through the Great Lakes, is the longest unmilitarized border in the world, perhaps in the history of the world. The last time hostile shots were fired was in 1813, when naval forces of the fledgling United States encountered a hostile British flotilla on Lake Erie and achieved a momentous naval victory. The captain of the American fleet, Oliver Hazard Perry, gave the following memorable report of his success, "We have met the enemy and he is ours."

Twenty years ago, in honor of the first Earth Day, cartoonist Walt Kelly's comic strip character Pogo provided a modern gloss to those old watchwords: "We have met the enemy and he is us." The truth of those words is especially evident in the environmental history of the Great Lakes. Since 1970 the friendship between the United States and Canada has led to environmental improvements in the Great Lakes, as well as to an honest appraisal of the work that remains to be done. During the next 20 years, the entire world will see reflected in the mirror of the Great Lakes what two "great contrasting nations" can accomplish through friendship and a shared resolve to restore a common heritage.

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34. Hoffman, D.J., et al., "Embryotoxicity, teratogenicity and aryl hydrocarbon hydroxylase activity in Forster's terns on Green Bay, Lake Michigan," *Environ. Research* (1987), 42:176-184; also see Kubiak, T.J., et al., "Microcontaminants and reproductive impairment of the Forster's tern on Green Bay, Lake Michigan—1983," *Archives of Environmental Contamination and Toxicology* (1989), 18.

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36. Ludwig and Kurito, page 205.

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41. Personal communication with V. Adamkus, Regional Administrator, U.S. EPA Region V, Chicago, IL (February 1989).

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57. Great Lakes Water Quality Board, *1989 Report on Water Quality*, page 90.

58. Great Lakes Water Quality Board, *1989 Report on Water Quality*, page 97.

59. Great Lakes National Program Office, *U.S. Progress in Implementing Water Quality*, Chapter 3.

60. Zarull, M.A., and C.J. Edwards, *A Review of Lake Superior Water Quality with Emphasis on the 1983 Intensive Survey*, Report to the Surveillance Work Group, Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario (1987).

61. *1987 Report on Great Lakes Water Quality*, pages 78-79.

62. Makarewicz, J.C., *Phytoplankton and Zooplankton in Lake Erie, Huron and Michigan: 1983*, EPA Great Lakes Program Office EPA-905/2-87-002, GLNPO Report No. 06 (April 1987), pages 94-100.

63. Great Lakes Water Quality Board, *1987 Report on Water Quality*, page 80.

64. Great Lakes Water Quality Board, *1987 Report on Water Quality*, pages 80-84.

65. Pennsylvania and Ohio were the only Great Lakes states without a phosphate detergent ban. The Ohio phosphate law was not passed until 1988. Governor Robert Casey of Pennsylvania signed a phosphate detergent bill in 1989. The Province of Ontario has a phosphate bill that is more permissive than U.S. counterparts.

66. Nicholls, K.H., and D.H. Hurley, "Recent changes in the phytoplankton of the Bay of Quinte, Lake Ontario: the relative importance of fish, nutrients, and other factors," *Can. J. Fish Aquat. Sci.* (1989), 46:770.

67. Great Lakes National Program Office, *Five Year Strategy*, page 111.

Appendix A

Selected NEPA Cases—1989

The Supreme Court

The Supreme Court addressed three major NEPA issues in two 1989 cases, *Robertson* v. *Methow Valley Citizen Council*[1] and *Marsh* v. *Oregon Natural Resources Council*[2]. The first issue was whether NEPA requires an agency to prepare worst case analyses in EISs. The second was whether there is a substantive requirement under NEPA that agencies prepare and adopt mitigation plans. The third issue went to what standard of judicial review courts should apply to determine whether to review an agency action.

Worst Case Analysis

In *Methow Valley*, plaintiffs had challenged the adequacy of a Forest Service Environmental Impact Statement (EIS) drafted for a major downhill ski resort. Plaintiffs contended that the EIS should have included a "worst case" analysis on possible impacts of air pollution from the ski resort. The Court disagreed, overruling an appellate court decision that such analyses were required. The Court found that CEQ's 1988 amendment of 40 CFR 1502.22; (1) specifically revoked the need for a specific worst case analysis and (2) replaced it with a requirement that agencies faced with scientific uncertainty or unavailable information concentrate on the reasonably foreseeable environmental consequences, including low probability, catastrophic impacts.[3] The Court pointed out that even if a doctrine under NEPA had been developed by the courts, if CEQ's regulatory revisions were based on good reason, "the new regulation is entitled to substantial deference."[4]

Mitigation

Plaintiffs had also contended in *Methow Valley* that the Forest Service was required to formulate and adopt a mitigation plan for reducing off-site air pollution effects on mule deer populations. The Court, though, reiterated its long standing view of the requirements set out in Section 102(2)(A) as procedural, rather than as substantive.[5] The Court made it absolutely clear that a federal agency must take a hard look at the environmental consequences of their actions, which includes a discussion of mitigation measures. "To be sure, one important ingredient of an EIS is the discussion of steps that can be taken to mitigate adverse environmental consequences."[6] This is, however, is fundamentally different, stated the Court, from "a substantive requirement that a complete mitigation plan be actually formulated and adopted."[7]

Standard of Review

In the *Marsh* case, plaintiffs had contended that the Corps of Engineers was required to supplement an EIS on a proposed dam in Oregon's Rogue River Basin. The Court in *Marsh* affirmed that the standard for determining whether a supplemental EIS is required is that standard set out in CEQ's regulations: whether there are significant new circumstances or information relevant to the environmental impact of the proposed action.[8] As in *Methow Valley*, the Court stated that CEQ's regulations are entitled to "substantial deference."[9] The Court further held that agencies should utilize a "rule of reason" analysis when interpreting CEQ's regulations concerning when an EIS is necessary.

The standard of review that applies to the courts when reviewing an agency decision to not supplement an EIS is a separate issue, also decided in *Marsh*. In this case the Court declared that the standard of review is controlled by the "arbitrary and capricious" standard of the Administrative Procedure Act (APA), as opposed to the "reasonableness" standard.[10] The Court held that the decision whether to supplement an EIS was a question of fact which requires agency expertise and that therefore, the more narrow APA standard should apply. The Court, however, made it clear that courts should not be unduly deferential to agencies; "[I]n the context of reviewing a decision not to supplement an EIS, courts should not automatically defer to the agency's express reliance on an interest in finality without carefully reviewing the record and satisfying themselves that the agency has made a reasoned decision based on its evaluation of the significance—or lack of significance—of the new information."[11]

The question that arises upon review of *Marsh* is whether the Court has indeed established a standard for judicial review for all NEPA cases, for decisions not to prepare EISs or only for decisions not to prepare supplemental EISs. The Court indicated that its decision was limited to supplemental EISs when it stated that its holding was controlling on the "narrow question before us of whether the Corps' determination that the FEIS need not be supplemented..."[12] The Court, however, did discuss several cases

in which the standard of review for the initial decision to not prepare an EIS was discussed. The Court further hedges the issue by stating in a footnote that differences in the two standards are difficult to discern and that, "our decision today will not require a substantial reworking of long-established NEPA law."[13]

U.S. Court of Appeals

Two appellate court decisions addressed issues posed by plaintiffs' attempts to obtain preliminary injunctions against actions by the U.S. Army Corps of Engineers (Corps).

In *South Carolina Department of Wildlife and Marine Resources* v. *Marsh*,[14] the district court had issued a preliminary injunction prohibiting the Corps from proceeding with the installation of pumped storage facilities at a South Carolina Dam. The court upheld the lower court's injunction as to operating the pumped storage generators, ruling that the court had adequately balanced the environmental injury against any possible hardships to the defendant.

The court, though, ruled that the injunction was too broad and should not have covered installation of the generators because installation would not in itself harm the environment. The court rejected plaintiff's argument that installation of the generators would commit so much money to the project that economic considerations would prevent the Corps from making an objective decision. The decision does not mention NEPA's requirement to assess the commitment of irretrievable resources nor CEQ's regulation at 40 C.F.R. 1506.1(c)(3) which states that agencies shall not undertake any action which may significantly affect the environment unless that action "will not prejudice the ultimate decision on the program. Interim action prejudices the ultimate decision on the program when it tends to determine subsequent development or limit alternatives."

In *Town of Huntington* v. *Marsh*,[15] plaintiffs—various small municipalities—had requested the granting of an injunction to prevent dumping of dredged material in the Long Island Sound pending issuance of an EIS by the Corps. The District Court had granted plaintiffs an injunction after an oral hearing in which various affidavits were presented. The appellate court, however, noted that oral hearings were not adequate and remanded the case to the district court for "evidentiary hearings." The court stated that consideration should be given "to the question whether plaintiff had met its burden to establish some actual or threatened injury to 'the physical, chemical and biological balance' of the dump site."[16]

U.S. District Court

In *Sierra Club* v. *Marsh*,[17] the court issued a lengthy opinion in which case law and CEQ regulations and guidance were examined in connection with (1) the use of contractors, and (2) the supplementing of EISs. In *Sierra Club*, plaintiffs had requested declaratory and injunctive relief halting construction of a marine dry cargo terminal due to the fact that certain consultants who had written portions of the EIS were not listed in the EIS. The court, citing CEQ's regulations and "Forty Questions" guidance, found that where a consultant had actually prepared sections of an EIS, the agency must list those preparers in the EIS and must obtain conflict of interest disclosure statements from the consultant,[18] even where a state agency oversaw the preparation of that EIS. The court also found that while an agency should disclose a consultant's prior involvement in a project, this did not automatically disqualify them from working on an EIS.

The court made an extensive analysis of the case law, including the Supreme Court's decision in *Marsh*,[19] in deciding to what extent an agency must examine and document the need to supplement an EIS. Plaintiffs had asserted that the environmental

effect of a newly proposed, larger port complex was new information that should have been assessed in a supplemental EIS. The court agreed, stating that the administrative record of the agency, "does not provide the kind of detailed explanation contemplated by NEPA; it neither evinces careful consideration of the decision not to prepare a supplemental EIS, nor the rationale for the decision, much less that the agency evaluated specific potential impacts."[20]

In *Atlantic Terminal Urban Renewal Area Coalition* v. *New York City Department of Environmental Protection*,[21] the court addressed issues concerning statutory delegation of NEPA responsibilities and the necessity for NEPA litigants to participate in administrative proceedings. Plaintiffs in *Atlantic* had contended that even though HUD had properly delegated authority for preparation of EISs to a local government,[22] that HUD was still responsible for the substantive adequacy of the EIS. The court disagreed, stating that the Housing and Community Development Amendments of 1981 intended that where HUD had delegated the responsibility for the EIS to the local agency it is that agency that is legally responsible for the adequacy of the EIS and not HUD.

The local government defendants in *Atlantic* then argued that because the plaintiffs had failed to raise NEPA objections during the EIS public hearing and commenting process, the plaintiffs were precluded from bringing suit. The court disagreed and held that neither the judicial doctrines of latches nor preclusion, could be utilized to bar plaintiff's action. The court cited several cases for the proposition that laches and failure to exhaust administrative remedies are not favored in NEPA cases "given the public interest in a sound environmental analysis and the long-term consequences of any poorly considered action."[23]

Notes and References

1. 109 S. Ct. 1835 (1989).
2. 109 S. Ct. 1851 (1989).
3. 109 S. Ct. 1835, 1848 (1989).
4. 109 S. Ct. 1849 (1989).
5. 109 S. Ct. 1846 (1989).
6. 109 S. Ct. 1846 (1989).
7. 109 S. Ct. 1847 (1989).
8. 109 S. Ct. 1851, 1858 (1989) citing 40 C.F.R. 1502.9(c).
9. 109 S. Ct. 1851, 1858 (1989).
10. 5 U.S.C. § 706(2)(a) (1977). Many courts have been using the broader standard of "reasonableness" to decide whether to review an agency action. For a look at the case law concerning the two different standards *see* Hoskins, *Judicial Review of an Agency's Decision Not to Prepare an Environmental Impact Statement*, 18 ELR 10331 (1988).
11. 109 S. Ct. 1851, 1861 (1989).
12. 109 S. Ct. 1860 (1989).
13. 109 S. Ct. 1861, n.23 (1989).
14. 866 F.2d 97 (4th Cir. 1989).
15. 884 F.2d 648 (2d Cir. 1989).
16. 888 F.2d 654 (2d Cir. 1989).
17. 314 F. Supp. 539 (D. Maine 1989).
18. 40 C.F.R. 1506.5(c); *CEQ Forty Questions*, 46 Fed. Reg.18031.
19. 314 F. Supp. 539, 566 (D. Maine 1989).
20. 314 F. Supp. 570 (D. Maine 1989).
21. 705 F. Supp. 988 (D. N.Y. 1989).
22. 42 U.S.C. § 5304(f)(1) (1981).
23. 705 F. Supp. 988, 998 (D. N.Y. 1989).

Appendix B

Trends in NEPA Litigation

During 1988 NEPA cases filed against federal agencies numbered 91. As shown in Table B-1, 7 of the 91 cases resulted in injunctions. While an increase over 1987, the 7 injunctions filed were considerably lower than those of any other year. In Table B-2 the U.S. Army Corps of Engineers is listed as the most frequent defendant; 22 cases were filed against the agency in 1988. The Departments of Agriculture and Interior each had 15 lawsuits. The Department of Transportation had 10.

Table B-3 displays the types of complaints filed, the most common being no environmental impact statement when one should have been prepared. The second most common complaint was the adequacy of the environmental impact statement. Individual or citizen groups were the most frequent plaintiffs with 35 as indicated in Table B-4. Environmental groups were the second most frequent plaintiffs with 31. Table B-5 shows the number of plaintiffs and issues by agency.

See Table B-6a and Table B-6b for draft, final, and supplemental environmental impact statements filed by federal agencies during 1988 and 1989, respectively. In 1988 environmental impact statements filed numbered 430, and 370 were filed in 1989.

Table B-1.—Cumulative NEPA litigation survey, 1970–88[1].

YEAR	CASES FILED	INJUNCTIONS	MOST FREQUENT DEFENDANT	MOST FREQUENT PLAINTIFF	MOST COMMON COMPLAINT	SECOND COMMON COMPLAINT
1974	189		DOT; HUD			
1975	152					
1976	119		DOT; DOI; HUD	Citizen and Environmental Groups	No EIS	Inadequate EIS
1977	108		DOT; DOD; DOI	Cit. & Env. Gr.	No EIS	Inadequate EIS
1978	114		DOT; DOD; DOI; HUD; EPA	Cit. & Env. Gr. Individuals	No EIS	Inadequate EIS
1979	139	12	DOT; HUD; DOI; DOAg; DOD	Env. Gr.; Cit. Gr. & Ind.	No EIS	Inadequate EIS
1980	140	17	DOT; DOI; DOD; HUD; EPA	Ind. & Cit. Gr. Env. Gr.	No EIS	Inadequate EIS
1981	114	12	DOD; DOT; DOI; DOAg; HUD; NRC	Env. Gr.; Ind. & Cit. Gr.	No EIS	Inadequate EIS
1982	157	19	DOI; COE; DOT; DOAg; HUD; EPA	Ind. & Cit. Gr. Env. Gr.	Inadequate EIS	No EIS
1983	146	21	DOI; DOT; DOA; FERC; NRC	Ind. & Cit. Gr. Env. Gr.	No EIS	Inadequate EIS
1984	89	14	DOAg; DOI; DOT	Env. Gr.; Ind. & Cit. Gr.	Inadequate EIS	No EIS
1985	77	8	DOT; DOI; COE; FERC	Env. Gr.; Ind. & Cit. Gr.	No EIS	Inadequate EIS
1986	71	16	DOT; DOI; DOAg	Ind. & Cit. Gr.; Env. Gr.	No EIS	Inadequate EIS
1987	69	3	DOI; DOT; DOAg	Env. Gr.; Ind. & Cit. Gr.	No EIS	Inadequate EA & EIS
1988	91	7	COE; DOAg; DOI; DOT	Env. Gr.; Ind. & Cit. Gr.	No EIS	Inadequate EIS

[1]1970–75: A cumulative survey on these years was published in the 1976 Annual Report. By June 30, 1975, 332 NEPA cases had been completed, resulting in 54 injunctions; 322 cases were still pending with 65 injunctions. The most frequent defendants were the Departments of Transportation and Housing and Urban Development.

Table B-2.—NEPA cases by agency, 1988.

AGENCIES	NUMBER OF CASES FILED	NUMBER OF 1988 CASES RESULTING IN INJUNCTIONS	NUMBER OF INJUNCTIONS IN 1988 FROM PRE-1988 CASES
Federal Commerce Commission	2	0	0
Federal Energy Regulatory Commission	1	0	0
Environmental Protection Agency	2	0	0
Interstate Commerce Commission	4	0	0
U.S. Postal Service	2	0	0
Department of Agriculture	15	1	2
Department of the Army	1	0	0
Department of the Army: U.S. Army Corps of Engineers	22	3	0
Department of Commerce	2	0	0
Department of Energy	2	0	0
Department of Housing & Urban Development	6	0	0
Department of the Interior	15	2	0
Department of Transportation	10	0	0
Department of Treasury	1	0	0
Department of the Navy	4	1	0
Department of the Air Force	2	0	0
TOTAL	91	7	2

Table B-3.—Types of complaints filed under NEPA, 1988.

CAUSES OF ACTION	NUMBER OF 1988 CASES	NUMBER OF PRE-1988 CASES RESULTING IN INJUNCTIONS IN 1988
Inadequate Environmental Impact Statement	30	1
No Environmental Impact Statement, when one should have been prepared	32	0
Inadequate Environmental Assessment	16	1
No Environmental Assessment, when one should have been prepared	8	0
No Supplemental Environmental Impact Statement, when one should have been prepared	3	0
Other	11	0
TOTAL	100	2

Table B-4.—Plaintiffs for NEPA lawsuits, 1988.

TYPES OF PLAINTIFFS	NUMBER FOR 1988 CASES	NUMBER FOR PRE-1988 CASES RESULTING IN INJUNCTIONS IN 1988
Environmental Groups	31	2
Individuals or Citizen Groups	35	0
State Governments	10	0
Local Governments	5	1
Business Groups	8	0
Property Owners or Residents	4	0
Indian Tribes	2	0
TOTAL	95	3

Table B-5.—Statistics on plaintiffs and issues for cases, by agency, 1988.

AGENCY	FCC	FERC	EPA	ICC	USPC	USDA	ARMY	COE	DOC	DOE	HUD	DOI	DOT	TRES	NAVY	USAF
PLAINTIFF																
Environmental Groups		1	1	1		9		6	1	2		5	2	1	1	1
Individual Citizen Groups	1	1	1	2	1	1	1	8	1		1	7	6		4	
State Governments				1	1			6	1			1				
Local Governments				1				1					2		1	
Businesses				2		2		2				2				
Property Owners or Residents	1					2										1
Indian Tribes						2										
TOTAL	2	2	2	7	2	16	1	23	3	2	1	15	10	1	6	2
ISSUE																
Inadequate EIS		1				6	1	13			1	1	4		2	1
No EIS					2	2		5	1	2	3	8	4	1	2	2
Inadequate EA				1		6		4		1		4				
No EA					2				1		2	2			1	
No Supplemental EIS								1					2			
Other	2		2	3				1				3				
TOTAL	2	1	2	4	4	14	1	24	2	3	6	18	10	1	5	3

Table B-6a.—Environmental impact statements filed by federal agencies, 1988.

AGENCY	TOTALS BY SUBJECT MATTER	TOTALS
U.S. Department of Agriculture		68
Land Acquisition or Disposal Management, Jurisdiction Transfer	1	
Watershed Protection and Floodplain Control	11	
Parks, Recreation Areas, Wilderness Areas, National Seashores	8	
Forestry and Range Management	32	
Pesticides, Herbicides Use	4	
Irrigation, Desalination of Return Flows, Agriculture Water Supply	2	
Multi-purpose Impoundment	1	
Mining (non-energy)	3	
Comprehensive Resource Management	1	
Natural Gas and Oil: Drilling and Exploration	2	
Municipal and Industrial Water Supply Systems (except multi-purpose impoundments)	1	
Power Facilities: Hydroelectric	1	
Wildlife Refuges, Fish Hatcheries	1	
U.S. Department of Commerce		3
Wildlife Refuges, Fish Hatcheries	1	
Wetlands, Estuary and Ocean Use (Sanctuary, Disposal, etc.)	1	
Fisheries	1	
U.S. Department of Defense (Other Than Below)		0
Department of the Air Force		6
Defense Systems	1	
Military Installations (Conventional, Chemical, Nuclear, etc.)	3	
Munition Disposal	1	
Aircraft, Ships and Vehicles	1	
Department of the Army		8
Defense Systems	2	
Military Installations (Conventional, Chemical, Nuclear, etc.)	4	
Housing Subdivisions or New Communities	2	
Department of the Army, Corps of Engineers		69
Solid Waste	1	
Natural Gas and Oil: Drilling and Exploration	1	
Munition Disposal	1	
Munition and Industrial Water Supply Systems (except multi-purpose impoundments)	2	
Beach Erosion, Hurricane Protection, River/Lake Bank Stabilization	3	
Navigation	16	
Multi-purpose Impoundments	2	
Watershed Protection and Flood Control	30	
Dredge and Fill	6	
Other Water Projects	1	
Buildings for Federal Use	2	
Parks, Recreation Areas, Wilderness Areas, National Seashores	1	
Wetlands, Estuary and Ocean Use (Sanctuary, Disposal, Etc.)	2	
Land Acquisition or Disposal Management, Jurisdiction Transfer	1	

Table B-6a.—Environmental impact statements filed by federal agencies, 1988 (cont.).

AGENCY	TOTALS BY SUBJECT MATTER	TOTALS
Department of the Navy		6
Military Installations (Conventional, Chemical, Nuclear, etc.)	1	
Power Facilities: Conservation	1	
Housing Subdivisions and New Communities	1	
Defense Systems	2	
Research and Development	1	
U.S. Department of Energy		9
Power Facilities:		
Transmission	2	
Nuclear	1	
Conservation	2	
Research and Development	2	
Defense Systems	2	
U.S. Environmental Protection Agency		23
Wetlands, Estuary and Ocean Use (Sanctuary, Disposal, etc.)	12	
Mining (non-energy)	1	
Mining	1	
Regulatory Activities	2	
Sewage Treatment and Sewage Facilities	6	
Miscellaneous Information	1	
U.S. General Services Administration		3
Federal Building Construction	3	
U.S. Department of Housing and Urban Development		2
Housing Subdivision and New Communities	1	
Urban Programs	1	
U.S. Department of the Interior		117
Regulatory Activities	1	
Mining	7	
Natural Gas and Oil: Drilling and Exploration	5	
Transportation, Pipeline, Storage	1	
Power Facilities: Transmission	1	
Municipal and Industrial Water Supply	6	
Irrigation, Desalination of Return Flows, Agricultural Water Supply	2	
Multi-purpose Impoundments	1	
Other Water Projects	2	
Land Acquisition Disposal	2	
Parks, Recreation Areas, Wilderness Areas, National Seashores	39	
Wildlife Refuges, Fish Hatcheries	14	
Forestry and Range Management	17	
Mining (non-energy)	7	
Comprehensive Resource Management	8	
Wetlands, Estuary and Ocean Use (Sanctuary, Disposal, etc.)	2	
Hazardous and Toxic Substance Disposal	2	
U.S. Interstate Commerce Commission		0
U.S. Nuclear Regulatory Commission		2
Power Facility: Nuclear	1	
Nuclear Development	1	

Table B-6a.—Environmental impact statements filed by federal agencies, 1988 (cont.).

AGENCY	TOTALS BY SUBJECT MATTER	TOTALS
U.S. Tennessee Valley Authority		0
U.S. Department of Transportation		96
Road Construction	83	
Bridge Permits	4	
Airport Improvements	5	
Mass Transportation	4	
U.S. Federal Energy Regulatory Commission		9
Natural Gas and Oil: Transportation, Pipeline, Storage	4	
Power Facilities: Hydroelectric	3	
Miscellaneous Information	2	
U.S. Department of Justice		6
Prison Construction	6	
U.S. National Aeronautics and Space Administration		3
Space Programs	3	
TOTAL FEDERAL EISs		430

Table B-6b.—Environmental impact statements filed by federal agencies, 1989.

AGENCY	TOTALS BY SUBJECT MATTER	TOTALS
U.S. Department of Agriculture		89
Road Construction	1	
Land Acquisition or Disposal, Management Jurisdiction Transfer	1	
Watershed Protection and Floodplain Control	6	
Parks, Recreation Areas, Wilderness Areas, National Seashores	19	
Forestry and Range Management	43	
Pesticides, Herbicides Use	8	
Irrigation, Desalination of Return Flows, Agriculture Water Supply	3	
Multi-Purpose Impoundments	1	
Mining (non-energy)	4	
Natural Gas and Oil: Transportation, Pipeline Storage	2	
Special Development (Expos, Bicentennials, Olympics, etc.)	1	
U.S. Department of Commerce		5
Wetlands, Estuary and Ocean Use (Sanctuary, Disposal, etc.)	4	
Fisheries	1	
U.S. Department of Defense (Other Than Below)		0
Department of the Air Force		11
Defense Systems	1	
Military Installations (Conventional, Chemical, Nuclear, etc.)	8	
Space Programs	1	
Sewage Treatment and Sewage Facilities	1	

Table B-6b.—Environmental impact statements filed by federal agencies, 1989 (cont.).

AGENCY	TOTALS BY SUBJECT MATTER	TOTALS
Department of the Army		9
Defense Systems	3	
Military Installations (Conventional, Chemical, Nuclear, etc.)	5	
Munition Disposal	1	
Department of the Army, Corps of Engineers		40
Solid Waste	1	
Municipal and Industrial Water Supply Systems (except multi-purpose impoundments)	2	
Beach Erosion, Hurricane Protection, River/Lake Bank stabilization	3	
Navigation	9	
Multi-purpose Impoundments	1	
Watershed Protection and Flood Control	15	
Dredge and Fill	2	
Other Water Projects	2	
Pesticides, Herbicides Use	1	
Parks, Recreation Areas, Wilderness Areas, National Seashores	1	
Wetlands, Estuary and Ocean Use (Sanctuary, Disposal, etc.)	2	
Bridge Permits	1	
Department of the Navy		3
Military Installations (Conventional, Chemical, Nuclear, etc.)	2	
Defense Systems	1	
Department of the Navy, Marine Corps		1
Military Installations (Conventional, Chemical, Nuclear, etc.)	1	
U.S. Department of Energy		6
Power Facilities:		
Transmission	2	
Fossil	2	
Nuclear Development (e.g., Fuel, Reactors)	1	
Radioactive Waste Disposal	1	
U.S. Environmental Projection Agency		25
Wetlands, Estuary and Ocean Use (Sanctuary, Disposal, etc.)	14	
Mining (non-energy)	1	
Mining	1	
Regulatory Activities	2	
Sewage Treatment and Sewage Facilities	6	
Miscellaneous Information	1	
U.S. General Services Administration		0
U.S. Department of Housing and Urban Development		7
Housing Subdivisions and New Communities	5	
Urban Programs	2	
U.S. Department of the Interior		61
Mining	7	
Natural Gas and Oil: Drilling and Exploration	4	
Power Facilities: Hydroelectric	2	

Table B-6b.—Environmental impact statements filed by federal agencies, 1989 (cont.).

AGENCY	TOTALS BY SUBJECT MATTER	TOTALS
Municipal and Industrial Water Supply	2	
Irrigation, Desalination of Return Flows, Agricultural Water Supply	1	
Multi-purpose Impoundments	3	
Other Water Projects	2	
Land Acquisition or Disposal	3	
Parks, Recreation Areas, Wilderness Areas, National Seashores	14	
Forestry and Range Management	10	
Mining (non-energy)	7	
Comprehensive Resource Management	3	
Hazardous and Toxic Substance Disposal	1	
Miscellaneous Information	1	
Road Construction	1	
U.S. Interstate Commerce Commission		0
U.S. Nuclear Regulatory Commission		3
Power Facility: Nuclear	1	
Radioactive Waste Disposal	1	
Power Facility: Conservation and Other	1	
U.S. Tennessee Valley Authority		0
U.S. Department of Transportation		90
Road Construction	81	
Bridge Permits	1	
Airport Improvements	5	
Mass Transportation	3	
U.S. Federal Energy Regulatory Commission		4
Natural Gas and Oil: Transportation, Pipeline Storage	2	
Power Facilities: Hydroelectric	2	
U.S. Department of Justice		13
Prison Construction	13	
U.S. National Aeronautics and Space Administration		2
Space Programs	2	
U.S. Postal Service		1
Building for Federal Use	1	
TOTAL FEDERAL EISs		370

Appendix C

List of International Treaties and Other Agreements in the Field of the Environment

Convention Concerning the Use of White Lead in Painting, Geneva, 1921
To protect workers from exposure to white lead and sulphate of lead and of all products containing these pigments.

Convention Relative to the Preservation of Fauna and Flora in Their Natural State, London, 1933
To preserve the natural fauna and flora of certain parts of the world, particularly of Africa, by means of national parks and reserves, and by regulation of hunting and collection of species.

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* *From Register of International Treaties and Agreements in the Field of the Environment, Nairobi (May 1989), UNEP/GC.15/Inf.2*

Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere, Washington, 1940

To preserve all species and genera of native American fauna and flora from extinction, and to preserve areas of extraordinary beauty, striking geological formations or aesthetic, historic, or scientific value.

International Convention for the Regulation of Whaling (as amended), Washington, 1946

To protect all species of whales from overfishing and safeguard for future generations the great natural resources represented by whale stocks. To establish a system of international regulation for the whale fisheries to ensure proper conservation and development of whale stocks.

Convention for the Establishment of an Inter-American Tropical Tuna Commission, Washington, 1949

To maintain populations of yellow fin and skipjack tuna in the eastern Pacific Ocean to permit maximum sustained catches year after year.

Agreement for the Establishment of a General Fisheries Council for the Mediterranean (as amended), Rome, 1949

The development and proper utilization of the resources of the Mediterranean and contiguous waters through international cooperation.

International Convention for the Protection of Birds, Paris, 1950

To protect birds in the wild state, considering that in the interests of science, the protection of nature and the economy of each nation, all birds should as a matter of principle be protected.

Convention for the Establishment of the European and Mediterranean Plant Protection Organization (as amended), Paris, 1951

To prevent the introduction and spread of pests and diseases of plants and plant products.

International Plant Protection Convention, Rome, 1951

To maintain and increase international cooperation in controlling pests and diseases of plants and plant products, and in preventing their introduction and spread across national boundaries.

Agreement Concerning Measures for Protection of the Stocks of Deep-sea Prawns (*Pandalus borealis*), European Lobsters (*Homarus vulgaris*), Norway Lobsters (*Nephrops norvegicus*), and Crabs (*Cancer pagurus*) (as amended), Oslo, 1952

To protect the stocks of the four species of crustacea.

International Convention for the High Seas Fisheries of the North Pacific Ocean (as amended), Tokyo, 1952

To ensure maximum sustained productivity of the fishery resources of the north Pacific Ocean, and to coordinate research and conservation measures to this end.

International Convention for the Prevention of Pollution of the Sea by Oil, London, 1954 (as amended on 11 April 1962 and 21 October 1969)

To take action to prevent pollution of the sea by oil discharged from ships.

Amendments to the International Convention for the Prevention of Pollution of the Sea by Oil, 1954, Concerning Tank Arrangements and Limitation of Tank Size, London, 1971

To regulate tank arrangements and limit tank size in oil tankers in order to avoid the possibility of serious environmental pollution resulting from a single accident involving a tanker.

Plant Protection Agreement for the South East Asia and Pacific Region (as amended), Rome, 1956

To prevent the introduction into and spread within the region of destructive plant diseases and pests.

Interim Convention on Conservation of North Pacific Fur Seals (as amended) Washington, 1957

To achieve maximum sustainable productivity from the fur seal resources of the North Pacific, and to conduct adequate scientific research to this end.

Convention Concerning Fishing in the Waters of the Danube, Bucharest, 1958

The rational utilization and expansion of the fish stocks in the Danube, through cooperation on a scientific basis.

Convention on the Continental Shelf, Geneva, 1958

To define and delimit the rights of States to explore and exploit the natural resources of the continental shelf.

Convention on Fishing and Conservation of the Living Resources of the High Sea, Geneva, 1958

Through international cooperation, to solve the problems involved in the conservation of the living resources of the high seas, considering that through the development of modern techniques some of these resources are in danger of being overexploited.

Convention on the High Seas, Geneva, 1958

To codify the rules of international law relating to the high seas.

Northeast Atlantic Fisheries Convention, London, 1959

To ensure the conservation and rational exploitation of the fish stocks of the northeast Atlantic Ocean and adjacent waters.

Convention Concerning Fishing in the Black Sea (as amended), Varna, 1959

To ensure the rational utilization of the fishery resources and the development of marine fishing in the Black Sea.

The Antarctic Treaty, Washington, 1959

To ensure that Antarctica is used for peaceful purposes, for international cooperation in scientific research, and does not become the scene or object of international discord.

Agreement Concerning Cooperation in the Quarantine of Plants and Their Protection Against Pests and Diseases, Sofia, 1959

To expand cooperation in the quarantine of plants and their protection from pests, diseases, and weeds, and to coordinate measures in respect of quarantine of plants, the control of pests and diseases of agricultural plants, and the control of weeds.

Convention Concerning the Protection of Workers Against Ionizing Radiations, Geneva, 1960

To protect workers, as regards their health and safety, against ionizing radiations.

Convention on Third Party Liability in the Field of Nuclear Energy (as amended), Paris, 1960

To ensure adequate and equitable compensation for persons who suffer damage caused by nuclear incidents, while ensuring that the development of nuclear energy for peaceful purposes is not thereby hindered. To unify the basic rules in various countries relating to liability incurred for such damage.

Convention Supplementary to the Paris Convention on Third Party Liability in the Field of Nuclear Energy (as amended), Brussels, 1963

To supplement the measures contained in the Paris Convention with a view to increasing the amount of compensation for damage which might result from the use of nuclear energy for peaceful purposes.

Protocol Concerning the Constitution of an International Commission for the Protection of the Moselle Against Pollution, Paris, 1961

To protect the Moselle River against pollution.

International Convention on the Protection of New Varieties of Plants, Paris, 1961

To recognize and protect the rights of breeders of new varieties of plants and their successors in title.

Convention on the African Migratory Locust, Kano, 1962

To maintain on an international basis the preventive control of the African migratory locust and to extend such control to other species of migratory Acrididae.

Agreement Concerning Cooperation in Marine Fishing, Warsaw, 1962

To foster cooperation in the development of marine fishing, fishing techniques, fish processing technology, and scientific research into the condition of living marine resources.

Agreement Concerning the International Commission for the Protection of the Rhine Against Pollution (as amended), Berne, 1963

To maintain cooperation between the riparian States in preventing pollution and improving the quality of the waters of the Rhine.

Vienna Convention on Civil Liability for Nuclear Damage, Vienna, 1963

To establish minimum standards to provide financial protection against damage resulting from peaceful use of nuclear energy.

Optional Protocol Concerning the Compulsory Settlement of Disputes, Vienna, 1963

To bring any dispute arising out of the interpretation or application of the Convention to the compulsory jurisdiction of the International Court of Justice, unless some other form of settlement has been agreed upon by the parties within a reasonable period.

Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water, Moscow, 1963

To obtain an agreement on general and complete disarmament under strict international control in accordance with the objectives of the United Nations; to put an end to the armaments race and eliminate incentives to the production and testing of all kinds of weapons, including nuclear weapons.

Agreement for the Establishment of a Commission for Controlling the Desert Locust in the Eastern Region of its Distribution Area in Southwest Asia (as amended), Rome, 1963

Through the establishment of a commission within the framework of FAO, to promote national and international research and action to control the desert locust in the region (Afghanistan, India, the Islamic Republic of Iran, Pakistan, and any territories adjacent to them).

Convention and Statute relating to the Development of the Chad Basin (as amended), Fort-Lamy (N'Djamina), 1964

To intensify cooperation and efforts in the development of the Chad Basin and to establish an institution for this purpose.

Convention for the International Council for the Exploration of the Sea (as amended), Copenhagen, 1964

To provide a new constitution for the International Council for the Exploration of the Sea established in Copenhagen in 1902.

Agreement for the Establishment of a Commission for Controlling the Desert Locust in the Near East (as amended)

Through the establishment of a commission within the framework of FAO, to promote national and international research and action to control the desert locust in the region.

International Convention for the Conservation of Atlantic Tunas, Rio de Janeiro, 1966

To maintain populations of tuna and tuna-like fish in the Atlantic Ocean at levels permitting the maximum sustainable catch for food and other purposes.

Treaty of Principles Governing the Activities of States in the Exploration and Use of Outer Space Including the Moon and Other Celestial Bodies, London, Moscow, Washington, 1967

To establish an international legal regime for the exploration and use of outer space.

Phyto-Sanitary Convention for Africa, Kinshasa, 1967

To control and eliminate plant diseases in Africa and prevent the introduction of new diseases.

African Convention on the Conservation of Nature and Natural Resources, Algiers, 1968

To encourage individual and joint action for the conservation, utilization, and development of soil, water flora and fauna for the present and future welfare of mankind, from an economic, nutritional, scientific, educational, cultural, and aesthetic point of view.

European Agreement on the Restriction of the Use of Certain Detergents in Washing and Cleaning Products, Strasbourg, 1968

To protect the supply of water for the population, industry, agriculture, and other business occupations, and the natural aquatic fauna and flora, in particular in so far as they contribute to human well-being, and to foster the unhindered enjoyment of places devoted to leisure and sport.

European Convention for the Protection of Animals During International Transport, Paris, 1968

To safeguard, as far as possible, animals in transport from suffering through the adoption of common provisions regarding the international transport of animals.

European Convention on the Protection of the Archeological Heritage, London, 1969

To apply stringent scientific methods to archaeological research and discoveries to preserve their full historical significance; to prevent illicit excavation and through education to give archaeological excavations their full scientific significance.

Agreement for Cooperation in Dealing with Pollution of the North Sea by Oil, Bonn, 1969

To ensure cooperation between the coastal states in providing manpower, supplies, equipment, and scientific advice at short notice to deal with discharges of oil or other noxious or hazardous substances in the North Sea.

Convention on the Conservation of the Living Resources of the southeast Atlantic, Rome, 1969

To achieve cooperation in the conservation and rational exploitation of the living resources of the southeast Atlantic Ocean.

International Convention on Civil Liability for Oil Pollution Damage (as amended), Brussels, 1969

To ensure that adequate compensation is available to persons who suffer damage caused by pollution resulting from ships. To standardize international rules and procedures for determining questions of liability and adequate compensation in such areas.

International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, Brussels, 1969

To enable countries to take action on the high seas in cases of a maritime casualty resulting in danger of oil pollution of sea and coastlines; to establish that such action would not affect the principle of freedom of the high seas.

Protocol Relating to Intervention on the High Seas in Cases of Marine Pollution by Substances Other than Oil, London, 1973

To enable states to take action on the high seas in cases of maritime casualties resulting in grave and imminent danger of pollution to their coastline or related interests by substances other than oil.

Benelux Convention on the Hunting and Protection of Birds (as amended), Brussels, 1970

To harmonize legislation and regulations relating to hunting and the protection of wild birds in the three contracting states.

Agreement for the Establishment of a Commission for Controlling the Desert Locust in Northwest Africa (as amended), Rome, 1970
Through the establishment of a commission within the framework of FAO, to promote national and international research and action to control the desert locust in the region.

Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Ramsar, 1971
To stem the progressive encroachment on and loss of wetlands now and in the future, recognizing the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value.

Protocol to Amend the Convention on Wetlands of International Importance Especially as Waterfowl Habitat, Paris, 1982
To render the Convention more effective.

Treaty on the Prohibition of the Emplacement of Nuclear Weapons and other Weapons of Mass Destruction on the Seabed and the Ocean Floor and in the Subsoil Thereof, London, Moscow, Washington, 1971
To exclude the seabed, the ocean floor, and the subsoil thereof from the arms race as a step towards disarmament, the reduction of international tensions, and the maintenance of world peace.

Convention Relating to Civil Liability in the Field of Maritime Carriage of Nuclear Material, Brussels, 1971
Further to the Paris Convention of 29 July 1960 and the Vienna Convention of 21 May 1963, to ensure that the operator of nuclear installations will be exclusively liable for damage caused by a nuclear incident occurring in the course of maritime carriage of nuclear material.

International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (as amended), Brussels, 1971
To supplement the International Convention on Civil Liability for Oil Pollution Damage, 1969; to ensure that adequate compensation is available to persons who suffer damage caused by pollution resulting from the escape or by discharge of oil from ships; and to ensure that the oil cargo interests bear a part of the economic consequences of such oil pollution damage, to the relief of the shipping industry.

Convention Concerning Protection Against Hazards of Poisoning Arising from Benzene, Geneva, 1971
To protect workers from hazards arising from the production, handling, or use of benzene.

Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (as amended), Oslo, 1972
To control the dumping of harmful substances from ships and aircraft in the sea.

Convention Concerning the Status of the Senegal River, and Convention Establishing the Senegal River Development Organization (as amended), Nouakchott, 1972
To promote cooperation among the riparian states of the Senegal River in the management and development of its resources.

Convention for the Conservation of Antarctic Seals, London, 1972
To promote and achieve the protection, scientific study, and rational use of Antarctic seals, and to maintain a satisfactory balance within the ecological system of the Antarctic.

Convention on the Prohibition of the Development, Production, and Stockpiling of Bacteriological (Biological) and Toxin Weapons, and on their Destruction, London, Moscow, Washington, 1972
To prohibit the development of biological weapons and eliminate them, as a step toward general disarmament for the sake of all mankind.

Convention Concerning the Protection of the World Cultural and Natural Heritage, Paris, 1972
To establish an effective system of collective protection of the cultural and natural heritage of outstanding universal value, organized on a permanent basis and in accordance with modern scientific methods.

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (as amended), London, Mexico City, Moscow, Washington, 1972
To control pollution of the sea by dumping, and to encourage regional agreements supplementary to the convention.

Convention on International Trade in Endangered Species of Wild Fauna and Flora, Washington, 1973
To protect certain endangered species from over-exploitation by means of a system of import/export permits.

Convention Establishing a Permanent Interstate Drought Control Committee for the Sahel, Ouagadougou, 1973
To protect the life of the peoples of the Sudano-Sahelian region and their economy against the drought.

Convention on Fishing and Conservation of the Living Resources in the Baltic Sea and Belts, Gdansk, 1973
To achieve greater and closer cooperation between the parties in order to maintain the maximum stable productivity of the living resources of the region.

International Convention for the Prevention of Pollution from Ships, London 1973
To preserve the marine environment by achieving the complete elimination of international pollution by oil and other harmful substances and the minimization of accidental discharge of such substances.

Protocol of 1978 Relating to the International Convention for the Prevention of Pollution from Ships, London, 1973
The 1978 Protocol modifies various provisions of the 1973 London Convention, and in particular of its Annex I. It also postpones the entry into force of Annex II of the convention for a period of at least three years.

Agreement on Conservation of Polar Bears, Oslo, 1973
To achieve protection of the polar bear as a significant resource of the Arctic region through further conservation and management measures.

Convention on the Protection of the Environment Between Denmark, Finland, Norway and Sweden, Stockholm, 1974

To protect and improve the environment through cooperation to ensure that activities under the jurisdiction of one state do not cause damage to the environment of other states.

Convention on the Protection of the Marine Environment of the Baltic Sea Area, Helsinki, 1974

To protect and enhance the marine environment of the Baltic Sea area by means of regional cooperation.

Convention on the Prevention of Marine Pollution from Land-Based Sources, Paris, 1974

The convention forms part of a comprehensive set of progressive and coherent measures to protect the marine environment from pollution.

Convention Concerning Prevention and Control of Occupational Hazards Caused by Carcinogenic Substances and Agents, Geneva, 1974

To protect workers against hazards arising from occupational exposure to carcinogenic substances and agents.

Agreement on an International Energy Program, Paris, 1974

To carry out a comprehensive program of energy cooperation within the framework of the International Energy Agency.

Convention for the Protection of the Mediterranean Sea Against Pollution, Barcelona, 1976

In the light of the special characteristics and vulnerability of the Mediterranean, to achieve international cooperation for a coordinated and comprehensive approach to the protection and enhancement of the marine environment in the Mediterranean area.

Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft, Barcelona, 1976

To control and in certain circumstances prohibit the dumping into the Mediterranean Sea area of wastes or other matter.

Protocol Concerning Cooperation in Combating Pollution of The Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency, Barcelona, 1976

To protect the coastal states and the marine ecosystem of the Mediterranean Sea against pollution by oil and other harmful substances.

Protocol for the Protection of the Mediterranean Sea Against Pollution from Land-Based Sources, Athens, 1980

To prevent, abate, combat, and control pollution of the Mediterranean area caused by discharges from rivers and coastal establishments.

Protocol Concerning Mediterranean Specially Protected Areas, Geneva, 1982

To protect and improve the state of the natural resources and natural sites of the Mediterranean Sea.

European Convention for the Protection of Animals Kept for Farming Purposes, Strasbourg, 1976

To protect animals kept for farming purposes, particularly in modern intensive stock farming.

Agreement Concerning the Protection of the Waters of the Mediterranean Shores, Monaco, 1976

To maintain cooperation between the three coastal states in preventing pollution and improving the quality of the waters of the Mediterranean shores, in the coastal region between 6° 7' longitude East and longitude 9° 8' East.

Convention on Conservation of Nature in the South Pacific, Apia, 1976

To take action for the conservation, utilization, and development of the natural resources of the South Pacific region through careful planning and management for the benefit of present and future generations.

Convention on the Protection of the Archeological, Historical, and Artistic Heritage of the American Nations (Convention of San Salvador), Santigo, 1976

To take steps at the national and international levels for effective protection of cultural treasures, and to fulfill the obligation to transmit the cultural heritage to coming generations.

Convention on the Protection of the Rhine Against Chemical Pollution, Bonn, 1976

To protect the Rhine against chemical pollution with the purpose of ameliorating the standards of water for potable and industrial use, navigation, etc.

Convention Concerning the Protection of the Rhine Against Pollution by Chlorides, Bonn, 1976

To protect the Rhine against chloride pollution with the purpose of ameliorating water standards.

Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, New York, 1976

To prohibit the military or other hostile use of such techniques in order to consolidate world peace and trust among nations.

Convention on Civil Liability for Oil Pollution Damage Resulting from Exploration for and Exploitation of Seabed Mineral Resources, London, 1977

To ensure that adequate compensation is available to victims of pollution damage from offshore activities, by means of the adoption of uniform rules and procedures for determining questions of liability and for providing such compensation.

Convention Concerning the Protection of Workers Against Occupational Hazards in the Working Environment Due to Air Pollution, Noise, and Vibration, Geneva, 1977

To protect workers against occupational hazards in the working environment.

Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution, Kuwait, 1978
To prevent, abate, and combat pollution of the marine environment.

Protocol Concerning Regional Cooperation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency, Kuwait, 1978
To enhance on a national and regional basis the existing measures for responding to pollution emergencies.

Treaty for Amazonian Cooperation, Brasilia, 1978
To promote the harmonious development of the Amazon region and permit equitable distribution of the benefits of such development among the contracting parties.

Convention on Future Multilateral Cooperation in the Northwest Atlantic Fisheries, Ottawa, 1978
To promote the conservation and optimum utilization of the fishery resources of the northwest Atlantic area within a framework appropriate to the regime of extended coastal state jurisdiction over fisheries, and accordingly to encourage international cooperation and consultation with respect to these resources.

Convention on the Conservation of Migratory Species of Wild Animals, Bonn, 1979
To protect those species of wild animals that migrate across or outside national boundaries.

European Convention for the Protection of Animals for Slaughter, Strasbourg, 1979
To ensure the protection of animals which are to be slaughtered.

Convention on the Conservation of European Wildlife and Natural Habitats, Berne, 1979
To conserve wild fauna and flora and their natural habitats, especially those species and habitats whose conservation requires the cooperation of several States, and to promote such cooperation.

Convention on the Physical Protection of Nuclear Material, Vienna, 1979
To facilitate the safe transfer of nuclear material and to establish effective measures for its physical protection.

Convention on Long-Range Transboundary Air Pollution, Geneva, 1979
To protect man and his environment against air pollution and to endeavor to limit and, as far as possible, gradually reduce and prevent air pollution, including long-range transboundary air pollution.

Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Long-Term Financing of the Cooperative Program for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP), Geneva, 1984
To provide for long-term funding after 1984 for the implementation of the Cooperative Program for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP).

Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution Concerning the Reduction of Sulphur Emissions or Their Transboundary Fluxes by at Least 30 Percent, Helsinki, 1985

To provide for a 30 percent reduction in sulphur emissions or transboundary fluxes by 1983.

Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution Concerning the Control of Emissions of Nitrogen or Their Transboundary Fluxes, Sofia, 1988

To provide for the control or reduction of nitrogen oxides and their transboundary fluxes.

Convention for the Conservation and Management of the Vicuna, Lima, 1979

To continue to promote the conservation and management of the vicuna.

Convention on the Conservation of Antarctic Marine Living Resources, Canberra, 1980

To safeguard the environment and protect the integrity of the ecosystem of the seas surrounding Antarctica, and to conserve Antarctic marine living resources.

European Outline Convention on Transfrontier Cooperation Between Territorial Communities or Authorities, Madrid, 1980

To facilitate and foster transfrontier cooperation between territorial communities or authorities of each contracting party.

Convention on Future Multilateral Cooperation in Northeast Atlantic Fisheries, London, 1980

To promote the conservation and optimum utilization of the fishery resources of the northeast Atlantic area within a framework appropriate to the regime of extended coastal state jurisdiction over fisheries, and accordingly to encourage international cooperation and consultation with respect to these resources.

Convention Creating the Niger Basin Authority and Protocol Relating to the Development Fund of the Niger Basin, Faranah, 1980

To transform the River Niger Commission into a Niger Basin Authority and to create a development fund to contribute to the development of the Niger Basin.

Convention for Cooperation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region, Abidjan, 1981

Protocol Concerning Cooperation in Combating Pollution in Cases of Emergency, Abidjan, 1981

To protect the marine environment, the coastal zones, and the related internal waters falling within the jurisdiction of the states of the west and central African region against pollution in cases of emergency.

Supplementary Protocol to the Agreement on Regional Cooperation in Combating Pollution of the southeast Pacific by Oil and Other Harmful Substances in cases of Emergency, Quito, 1983

To protect the marine environment of the southeast Pacific area against pollution by oil and other harmful substances in cases of emergency.

Protocol for the Protection of the southeast Pacific Against Pollution from Land-Based Sources, Quito, 1983

To prevent, abate, combat, and control pollution of the southeast Pacific area caused by discharges from rivers, coastal establishments or outfalls, or emanating from any other land-based sources within the territories of the coastal states.

Convention Concerning Occupational Safety and Health and the Working Environment, Geneva, 1981

To prevent accidents and injury to health by minimizing the causes of hazards inherent in the working environment.

Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment, Jiddah, 1982

To ensure rational human use of living and nonliving marine and coastal resources in a manner ensuring optimum benefit for the present generations, at the same time maintaining the potential of that environment to satisfy the needs and aspirations of future generations.

Protocol Concerning Regional Cooperation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency, Jiddah, 1982

To enhance measures for responding to pollution emergencies on a national and regional basis.

Convention for the Conservation of Salmon in the North Atlantic Ocean, Reykjavik, 1982

To promote the conservation, restoration, enhancement, and rational management of salmon stock in the north Atlantic Ocean through international cooperation, as well as the acquisition, analysis, and dissemination of appropriate scientific information.

Benelux Convention on Nature Conservation and Landscape Protection, Brussels, 1982

To preserve nature, natural areas, and the landscapes, especially in boundary regions.

United Nations Convention on the Law of the Sea, Montego Bay, 1982

To set up a comprehensive new legal regime for the sea and oceans and, as far as environmental provisions are concerned, to establish material rules concerning environmental standards as well as enforcement provisions dealing with pollution of the marine environment.

Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, Cartagena, 1983

To protect and manage the marine environment and coastal areas of the wider Caribbean region.

Protocol Concerning Cooperation in Combating Oil Spills in the Wider Caribbean Region, Cartagena, 1983

To provide a framework for regional cooperation and assistance in the event of an oil spill incident in the Caribbean region.

Agreement for Cooperation in Dealing with Pollution of the North Sea by Oil and Other Harmful Substances, Bonn, 1983

To ensure cooperation between the coastal States in providing manpower, supplies, equipment, and scientific advice at short notice to deal with discharges of oil or other harmful substances in the North Sea.

International Tropical Timber Agreement, Geneva, 1983

To provide an effective framework for cooperation and consultation between countries producing and consuming tropical timber, to promote the expansion and diversification of international trade in tropical timber and the improvement of structural conditions in the tropical timber market, to promote and support research and development with a view to improving forest management and wood utilization, and to encourage the development of national policies aimed at sustainable utilization and conservation of tropical forests and their genetic resources, and at maintaining the ecological balance in the regions concerned.

Vienna Convention for the Protection of the Ozone Layer, Vienna, 1985

To protect human health and the environment against adverse effects resulting form modifications of the ozone layer.

Montreal Protocol on the Substances that Deplete the Ozone Layer, Montreal, 1987

To protect the ozone layer by taking precautionary measures to control global emissions of substances that deplete it.

Convention for the Protection, Management, and Development of the Marine and Coastal Environment of the Eastern African Region, Nairobi, 1985

To protect and manage the marine environment and coastal areas of the east African region.

Protocol Concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region, Nairobi, 1985

To provide for the protection of threatened and endangered species of flora and fauna, and important natural habitats, in the east African region.

Protocol Concerning Cooperation in Combating Marine Pollution in Cases of Emergency in the Eastern African Region, Nairobi, 1985

To provide a framework for coordinated response in major spillages or oil and other harmful substances in the convention area.

Convention Concerning Occupational Health Services, Geneva, 1985

To establish and maintain a safe and healthy working environment and the adaption of work to the capabilities of workers in light of their state of physical and mental health.

South Pacific Nuclear Free Zone Treaty, Raratonga, 1985

To establish a nuclear free zone in the region and to keep the region free of environmental pollution by radioactive wastes.

ASEAN Agreement on the Conservation of Nature and Natural Resources, Kuala Lumpure, 1985

To promote joint and individual state action for the conservation and management of the natural resources of the ASEAN region.

Convention Concerning Safety in the Use of Asbestos, Geneva, 1986 To prevent and control the exposure of workers to asbestos and to protect them against health hazards due to occupational exposure to asbestos.

Convention on Early Notification of a Nuclear Accident, Vienna, 1986

To provide relevant information about nuclear accidents as early as possible in order that transboundary radiological consequences can be minimized.

Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, Vienna, 1986

To facilitate the prompt provision of assistance in the event of a nuclear accident or radiological emergency.

Convention for the Protection of the Natural Resources and Environment of the South Pacific Region, Noumea, 1986

To protect and manage the natural resources and environment of the South Pacific region.

Protocol for the Prevention of Pollution of the South Pacific Region by Dumping, Noumea, 1986

To prevent, reduce, and control pollution by dumping of wastes and other matter in the South Pacific.

Protocol Concerning Cooperation in Combating Pollution Emergencies in the South Pacific Region, Noumea, 1986

To enhance cooperation among the parties to protect the South Pacific region from threats and effects of pollution incidents.

Agreement on the Action Plan for the Environmentally Sound Management of the Common Zambezi River System, Harare, 1987

To coordinate the efforts of the parties in the sound management of the water resources and the environment of the Common Zambezi River System.

Convention on the Regulation of Antarctic Mineral Resource Activities, Wellington, 1988

To provide for principles, rules, and institutions to assess the possible impact on the environment of Antarctic mineral resource activities, to determine the acceptability of those activities, to govern the conduct of the activities, and to ensure that all such activities are undertaken in conformity with the convention. The aims of the convention being to prohibit activities that would cause damage to the environment or ecosystems of the Antarctic or affect global or regional climate patterns.

Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention, Vienna, 1988

To establish a special link between the Vienna Convention on Civil Liability for Nuclear Damage of 21 May, 1963, and the Paris Convention on Third Party Liability in the field of Nuclear Energy of 29 July, 1960, and eliminate possible conflicts arising from the simultaneous application of both conventions to a nuclear incident.

Appendix D

Environmental Declarations from the Economic Summit, Paris, 1989

33) There is growing awareness throughout the world of the necessity to preserve better the global ecological balance. This includes serious threats to the atmosphere, which could lead to future climate changes. We note with great concern the growing pollution of air, lakes, rivers, oceans, and seas; acid rain, dangerous substances; and the rapid desertification and deforestation. Such environmental degradation endangers species and undermines the well-being of individuals and societies.

Decisive action is urgently needed to understand and protect the earth's ecological balance. We will work together to achieve the common goals of preserving a healthy and balanced global environment in order to meet shared economic and social objectives and to carry out obligations to future generations.

34) We urge all countries to give further impetus to scientific research on environmental issues, to develop necessary technologies and to make clear evaluations of the economic costs and benefits of environmental policies.

The persisting uncertainty on some of these issues should not unduly delay our action. In this connection, we ask all countries to combine their efforts in order to improve observation and monitoring on global scale.

35) We believe that international cooperation also needs to be enhanced in the field of technology and technology transfer in order to reduce pollution or provide alternative solutions.

36) We believe that industry has a crucial role in preventing pollution at source, in waste minimization, in energy conservation, and in the design and

marketing of cost-effective clean technologies. The agriculture sector must also contribute to tackling problems such as water pollution, soil erosion, and desertification.

37) Environmental protection is integral to issues such as trade, development, energy, transport, agriculture, and economic planning. Therefore, environmental considerations must be taken into account in economic decisionmaking. In fact good economic policies and good environmental policies are mutually reinforcing.

In order to achieve sustainable development, we shall ensure the compatibility of economic growth and development with the protection of the environment. Environmental protection and related investment should contribute to economic growth. In this respect, intensified efforts for technological breakthrough are important to reconcile economic growth and environmental policies.

Clear assessments of the costs, benefits, and resource implications of environmental protection should help governments to make the necessary decisions on the mix of price signals (e.g., taxes or expenditures) and regulatory actions, reflecting where possible the full value of natural resources.

We encourage the World Bank and regional development banks to integrate environmental considerations into their activities. International organizations such as the OECD and the United Nations and its affiliated organizations, will be asked to develop further techniques of analysis which would help governments assess appropriate economic measures to promote the quality of the environment. We ask the OECD, within the context of its work on integrating environment and economic decisionmaking, to examine how selected environmental indicators could be developed. We expect the 1992 U.N. Conference on Environment and Development to give additional momentum to the protection of the global environment.

38) To help developing countries deal with past damage and to encourage them to take environmentally desirable action, economic incentives may include the use of aid mechanisms and specific transfer of technology. In special cases, ODA debt forgiveness and debt for nature swaps can play a useful role in environmental protection.

We also emphasize the necessity to take into account the interests and needs of developing countries in sustaining the growth of their economies and the financial and technological requirements to meet environmental challenges.

39) The depletion of the stratospheric ozone layer is alarming and calls for prompt action. We welcome the Helsinki conclusions related, among other issues, to the complete abandonment of the production and consumption of chlorofluorocarbons covered by the Montreal protocol as soon as possible and not later than the end of the century. Specific attention must also be given to those ozone-depleting substances not covered by the Montreal protocol. We shall promote the development and use of suitable substitute substances and technologies. More emphasis should be placed on projects that provide alternatives to chlorofluorocarbons.

40) We strongly advocate common efforts to limit emissions of carbon dioxide and other greenhouse gases, which threaten to induce climate change, endangering the environment and ultimately the economy. We strongly sup-

port the work undertaken by the Intergovernmental Panel on Climate Change, on this issue.

We need to strengthen the worldwide network of observatories to greenhouse gases and support the World Meteorological Organization initiative to establish a global climatological reference network to detect climate changes.

41) We agree that increasing energy efficiency could make a substantial contribution to these goals. We urge international organizations concerned to encourage measures, to improve energy conservation and, more broadly, efficiency in the use of energy of all kinds and to promote relevant techniques and technologies.

We are committed to maintaining the highest safety standards for nuclear power plants and to strengthening international cooperation in safe operation of power plants and waste management, and we recognize that nuclear power also plays an important role in limiting output of greenhouse gases.

42) Deforestation also damages the atmosphere and must be reversed. We call for the adoption of sustainable forest management practices, with a view to preserving the scale of world forests. The relevant international organizations will be asked to complete reports on the state of the world's forests by 1990.

43) Preserving the tropical forests is an urgent need for the world as a whole. While recognizing the sovereign rights of developing countries to make use of their natural resources, we encourage, through a sustainable use of tropical forests, the protection of all the species therein and the traditional rights to land and other resources of local communities. We welcome the German initiative in this field as a basis for progress.

To this end, we give strong support to rapid implementation of the Tropical Forest Action Plan which was adopted in 1986 in the framework of the Food and Agriculture Organization. We appeal to both consumer and producer countries, which are united in the International Tropical Timber Organization, to join their efforts to ensure better conservation of the forests. We express our readiness to assist the efforts of nations with tropical forests through financial and technical cooperation, and in international organizations.

44) Temperate forests, lakes and rivers must be protected against the effects of acid pollutants such as sulphur dioxide and nitrogen oxides. It is necessary to pursue actively the bilateral and multilateral efforts to this end.

45) The increasing complexity of the issues related to the protection of the atmosphere calls for innovative solutions. New instruments may be contemplated. We believe that the conclusion of a framework or umbrella convention on climate change to set out general principles or guidelines is urgently required to mobilize and rationalize the efforts made by the international community. We welcome the work under way by the United Nations Environment Program, in cooperation with the World Meteorological Organization, drawing on the work of the Intergovernmental Panel on Climate Change and the results of other international meetings. Specific protocols containing concrete commitments could be fitted into the framework as scientific evidence requires and permits.

46) We condemn indiscriminate use of oceans as dumping grounds for polluting waste. There is a particular problem with the deterioration of coastal waters. To ensure the sustainable management of the marine environment, we recognize the importance of international cooperation in preserving it and conserving the living resources of the sea. We call for relevant bodies of the United Nations to prepare a report on the state of the world's oceans.

We express our concern that national, regional and global capabilities to contain and alleviate the consequences of maritime oil spills be improved. We urge all countries to make better use of the latest monitoring and clean-up technologies. We ask all countries to adhere to and implement fully the international conventions for the prevention of oil pollution of the oceans. We also ask the International Maritime Organization to put forward proposals for further preventive action.

47) We are committed to ensuring full implementation of existing rules for the environment. In this respect, we note with interest the initiatives of the Italian government to host in 1990 a forum on international law for the environment with scholars, scientific experts and officials, to consider the need for a digest of existing rules and to give in-depth consideration to the legal aspects of environment at the international level.

48) We advocate that existing environmental institutions be strengthened within the United Nations system. In particular, the United Nations Environment Program urgently requires strengthening and increased financial support. Some of us have agreed that the establishment within the United Nations of a new institution may also be worth considering.

49) We have taken note of the report of the sixth conference on bioethics held in Brussels which examined the elaboration of a universal code of environmental ethics based upon the concept of the "human stewardship of nature."

50) It is a matter of international concern that Bangladesh, one of the poorest and most densely populated countries in the world, is periodically devastated by catastrophic floods.

We stress the urgent need for effective, coordinated action by the international community, in support of the Government of Bangladesh, in order to find solutions to this major problem which are technically, financially, economically, and environmentally sound. In that spirit, and taking account of help already given, we take note of the different studies concerning flood alleviation, initiated by France, Japan, United States, and the United Nations Development Program, which have been reviewed by experts from all our countries. We welcome the World Bank's agreement, following those studies, to coordinate the efforts of the international community so that a sound basis for achieving a real improvement in alleviating the effects of floods can be established. We also welcome the agreement of the World Bank to chair, by the end of the year, a meeting to be held in the United Kingdom by invitation of the Bangladesh Government, of the countries willing to take an active part in such a program.

51) We give political support to projects such as the joint project to set up an observatory of the Saharan areas, which answers the need to monitor the development of that rapidly deteriorating, fragile, arid region, in order to protect it more effectively.

Appendix E

Environmental Data and Trends

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Table 1
Total population, including armed forces overseas, 1900-1990

(millions)

Year	Population	Year	Population	Year	Population
1900	76.09	1931	124.15	1962	186.54
1901	77.58	1932	124.95	1963	189.24
1902	79.16	1933	125.69	1964	191.89
1903	80.63	1934	126.49	1965	194.30
1904	82.17	1935	127.36	1966	196.56
1905	83.82	1936	128.18	1967	198.71
1906	85.45	1937	128.96	1968	200.71
1907	87.01	1938	129.97	1969	202.68
1908	88.71	1939	131.03	1970	205.05
1909	90.49	1940	132.59	1971	207.66
1910	92.41	1941	133.89	1972	209.90
1911	93.86	1942	135.36	1973	211.91
1912	95.34	1943	137.25	1974	213.85
1913	97.23	1944	138.92	1975	215.97
1914	99.11	1945	140.47	1976	218.04
1915	100.55	1946	141.94	1977	220.24
1916	101.96	1947	144.70	1978	222.59
1917	103.41	1948	147.21	1979	225.06
1918	104.55	1949	149.77	1980	227.76
1919	105.06	1950	152.27	1981	230.14
1920	106.46	1951	154.88	1982	232.52
1921	108.54	1952	157.55	1983	234.80
1922	110.05	1953	160.18	1984	237.00
1923	111.95	1954	163.03	1985	239.28
1924	114.11	1955	165.93	1986	241.61
1925	115.83	1956	168.90	1987	243.92
1926	117.40	1957	171.98	1988	246.11
1927	119.04	1958	174.88	1989	248.25p
1928	120.51	1959	177.83	1990	250.41p
1929	121.77	1960	180.67		
1930	123.19	1961	183.69		

Source: U.S. Department of Commerce, Bureau of the Census. Current population reports, series P-25, nos. 521, 802, 990, 1018, and 1022. Washington, D.C.

Notes: Annual population estimate as of July 1. p=projected.

Table 2
Population growth rate, 1901-1990

(percent change)

Year	Growth rate	Year	Growth rate	Year	Growth rate
1901	2.0	1931	0.7	1961	1.6
1902	2.0	1932	0.6	1962	1.5
1903	1.9	1933	0.6	1963	1.4
1904	1.9	1934	0.7	1964	1.3
1905	2.0	1935	0.7	1965	1.2
1906	1.9	1936	0.6	1966	1.1
1907	1.8	1937	0.7	1967	1.1
1908	2.0	1938	0.8	1968	1.0
1909	2.0	1939	0.8	1969	1.0
1910	2.1	1940	0.9	1970	1.3
1911	1.6	1941	1.0	1971	1.2
1912	1.6	1942	1.3	1972	1.0
1913	2.0	1943	1.3	1973	0.9
1914	1.9	1944	1.2	1974	0.9
1915	1.4	1945	1.0	1975	1.0
1916	1.4	1946	1.5	1976	1.0
1917	1.4	1947	1.8	1977	1.0
1918	1.1	1948	1.7	1978	1.1
1919	0.5	1949	1.7	1979	1.2
1920	1.3	1950	1.7	1980	1.1
1921	2.0	1951	1.7	1981	1.0
1922	1.4	1952	1.7	1982	1.0
1923	1.7	1953	1.7	1983	0.9
1924	1.9	1954	1.8	1984	0.9
1925	1.5	1955	1.8	1985	1.0
1926	1.4	1956	1.8	1986	0.9
1927	1.4	1957	1.7	1987	0.9
1928	1.2	1958	1.7	1988	0.9
1929	1.0	1959	1.7	1989	0.9
1930	0.9	1960	1.6	1990	0.9

Source: U.S. Department of Commerce, Bureau of the Census. Current population reports, series P-25, nos. 521, 802, 990, 1018, and 1022. Washington, D.C.

Notes: Based on annual population estimate as of July 1. Data for 1989 and 1990 are projections.

Table 3
Components of total population change, 1940-1990

(millions)

Year	Births	Deaths	Net civilian immigration	Net change
1940	2.570	1.432	0.077	1.221
1945	2.873	1.549	0.162	1.462
1950	3.645	1.468	0.299	2.486
1955	4.128	1.537	0.337	2.925
1960	4.307	1.708	0.328	2.901
1965	3.801	1.830	0.373	2.315
1970	3.739	1.927	0.438	2.617
1975	3.144	1.894	0.449	2.165
1980	3.612	1.990	0.845	2.582
1985	3.761	2.087	0.650	2.325
1990	3.731	2.180	0.575	2.126

Source: U.S. Department of Commerce, Bureau of the Census. Current population reports, series P-25, nos. 952, 990, 1018, and 1023. Washington, D.C.

Notes: Based on annual population estimate as of July 1. Data for 1990 are projections.

Table 4
Age structure of total population, including armed forces overseas, 1940-1990

(millions)

Year	Population, by age class, in years							
	< 5	5-14	15-24	25-34	35-44	45-54	55-64	> 64
1940	10.6	22.3	24.0	21.5	18.4	15.6	10.7	9.0
1950	16.3	24.5	22.3	23.9	21.6	17.4	13.4	12.4
1960	20.3	35.7	24.6	22.9	24.2	20.6	15.6	16.7
1970	17.2	40.7	36.5	25.3	23.1	23.3	18.7	20.1
1980	16.5	34.8	42.7	37.6	25.9	22.8	21.8	25.7
1985	18.0	33.9	39.6	42.1	31.8	22.6	22.3	28.5
1990	18.4	45.6	26.1	43.9	37.9	25.5	21.4	31.6

Source: U.S. Department of Commerce, Bureau of the Census. 1975. Historical statistics of the United States: Colonial times to 1970, series A 30-37. Washington, D.C.

U.S. Department of Commerce, Bureau of the Census. Current population reports, series P-25, nos. 311, 519, 917, 1018, and 1022. Washington, D.C.

Note: Data for 1990 are projections.

Table 5
Population density, 1940-1987

(population per square mile)

Year	Contermin-ous U.S.	Counties in coastal regions				Balance of U.S.
		Pacific	Gulf	Atlantic	Great Lakes	
1940	44.4	64.1	44.8	244.4	140.9	28.5
1950	50.8	97.6	59.8	283.3	162.9	30.9
1960	60.2	142.7	83.1	341.6	197.3	34.3
1970	68.2	182.5	101.1	394.4	219.1	37.6
1980	76.0	215.8	134.1	414.9	222.4	42.8
1985	79.1	231.5	149.3	429.7	221.4	44.6
1987	81.6	248.3	155.3	445.1	222.4	45.6

Source: U.S. Department of Commerce, Bureau of the Census. Statistical abstract of the United States, annual. Washington, D.C.

Note: Coastal area includes 611 counties and independent cities which are entirely or or substantially within 50 miles of the U.S. coast.

Table 6
Gross national product, 1929-1990

(billions of dollars)

Year	Current dollars	1982 dollars
1929	103.9	709.6
1935	072.8	580.2
1940	100.4	772.9
1945	213.4	1,354.8
1950	288.3	1,203.7
1955	405.9	1,494.9
1960	515.3	1,665.3
1965	705.1	2,087.6
1970	1,015.5	2,416.2
1975	1,598.4	2,695.0
1980	2,732.0	3,187.1
1985	4,014.9	3,662.4
1989	5,233.2	4,142.6
1990	5,475.8	na

Source: U.S. Department of Commerce, Bureau of Economic Analysis. Survey of Current Business, quarterly issues. Washington, D.C.

Executive Office of the President, Council on Economic Advisers. 1990 Economic Report. Washington, D.C.

Notes: Data for 1990 are projections. na=not available.

Table 7
Expenditures for pollution abatement and control, in current and constant (1982) dollars, 1972-1987

(billions of dollars)

Year	Total		Pollution abatement		Regulation & monitoring		Research & development	
	Current	Constant	Current	Constant	Current	Constant	Current	Constant
1972	18.1	43.0	16.7	40.3	0.4	0.8	0.8	1.9
1973	21.8	48.8	20.4	45.8	0.5	1.0	0.9	2.0
1974	25.6	49.8	24.0	46.7	0.6	1.1	1.0	2.0
1975	30.2	53.5	28.4	50.4	0.7	1.1	1.1	2.0
1976	33.9	56.5	31.9	53.2	0.7	1.2	1.3	2.2
1977	37.6	58.7	35.3	55.1	0.8	1.2	1.5	2.3
1978	42.7	62.1	40.1	58.3	1.0	1.3	1.7	2.4
1979	48.7	63.3	45.9	59.5	1.1	1.4	1.8	2.4
1980	53.5	62.1	50.5	58.4	1.3	1.5	1.8	2.1
1981	57.5	60.3	54.3	57.0	1.4	1.5	1.8	1.9
1982	57.7	57.7	54.5	54.5	1.4	1.4	1.8	1.8
1983	61.8	60.0	58.1	56.5	1.4	1.3	2.3	2.3
1984	68.9	64.7	65.2	61.3	1.4	1.2	2.3	2.2
1985	74.6	68.1	71.0	64.9	1.3	1.1	2.4	2.2
1986	78.7	71.3	74.6	68.2	1.5	1.3	2.6	2.3
1987	81.1	71.4	76.9	67.8	1.5	1.2	2.7	2.3

Fraber, K.D. & G.L. Rutledge. 1986. Pollution abatement and control expenditures. Survey of Current Business, table 9, pp. 100-103 (July, 1986). U.S. Department of Commerce, Bureau of Economic Analysis. Washington, D.C.

Fraber, K.D. & G.L. Rutledge. 1989. Pollution abatement and control expenditures, 1984-87. Survey of Current Business, table 6, pp. 24-25 (June, 1989). U.S. Department of Commerce, Bureau of Economic Analysis. Washington, D.C.

Notes: Pollution abatement and control (PAC) spending is for goods and services that U.S. residents use to produce cleaner air and water and to dispose of solid waste. PAC spending consists of expenditures associated with pollution abatement, regulation and monitoring, and research and development. Totals may not agree with detail because of independent rounding.

Table 8
Expenditures for pollution abatement, by type of pollution, 1972-1987

(billions of dollars)

Year	Air		Water		Solid waste		Other	
	Current	Constant	Current	Constant	Current	Constant	Current	Constant
1972	5.6	14.6	8.5	19.7	3.3	7.1	-0.4	-1.1
1973	7.3	17.9	9.7	21.3	3.7	7.6	-0.4	-1.1
1974	9.1	18.3	11.2	21.5	4.3	7.9	-0.5	-1.0
1975	11.4	20.8	13.0	22.8	4.7	7.9	-0.7	-1.1
1976	12.6	21.7	14.9	24.5	5.2	8.4	-0.8	-1.3
1977	14.1	22.8	16.1	24.7	6.0	9.1	-0.9	-1.4
1978	15.7	23.8	19.0	26.6	6.5	9.5	-1.1	-1.5
1979	18.6	24.5	20.8	36.5	7.8	10.2	-1.3	-1.6
1980	21.9	24.7	21.3	24.7	8.8	10.7	-1.5	-1.7
1981	25.1	25.9	20.8	22.0	10.0	10.7	-1.6	-1.6
1982	25.0	25.0	21.2	21.2	9.6	9.6	-1.3	-1.3
1983	26.6	26.4	22.4	21.5	10.2	9.7	-1.2	-1.2
1984	29.6	28.6	25.2	23.3	11.8	10.8	-1.3	-1.3
1985	31.2	29.7	27.6	24.7	13.1	11.5	-1.0	-1.0
1986	31.2	30.6	29.7	26.4	14.7	12.3	-1.0	-1.1
1987	30.1	28.3	32.1	27.9	16.2	13.2	-1.5	-1.5

Fraber, K.D. & G.L. Rutledge. 1986. Pollution abatement and control expenditures. Survey of Current Business, table 9, pp. 100-103 (July, 1986). U.S. Department of Commerce, Bureau of Economic Analysis. Washington, D.C.

Fraber, K.D. & G.L. Rutledge. 1989. Pollution abatement and control expenditures, 1984-87. Survey of Current Business, table 6, pp. 24-25 (June,1989). U.S. Department of Commerce, Bureau of Economic Analysis. Washington, D.C.

Notes: Expenditures are attributed to the sector that performs the air or water pollution abatement or solid waste collection and disposal. Other includes expenditures for abatement of noise, radiation, and pesticide pollution, and business expenditures not assigned to another media. Totals may not agree with detail because of independent rounding. -=less than.

Table 9
Expenditures for pollution abatement, for selected industries, 1973-1986

(millions of dollars)

	Chemicals and allied products							
	Capital expenditures				Operating costs			
Year	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	395.9	164.4	214.6	16.8	502.3	174.1	247.6	80.2
1974	539.2	250.6	264.4	24.1	643.3	203.8	335.6	104.0
1975	780.2	359.5	387.7	35.0	807.4	249.9	430.9	126.7
1976	942.0	319.8	577.4	44.7	983.5	295.6	514.7	173.2
1977	982.5	339.9	593.1	49.6	1,238.3	335.5	685.2	217.6
1978	827.5	376.3	385.9	65.1	1,473.0	398.8	794.1	280.1
1979	770.9	314.6	360.7	95.6	1,667.5	485.3	895.2	287.0
1980	780.7	325.9	350.0	104.8	1,851.8	539.9	942.9	368.8
1981	752.8	335.0	322.2	95.6	2,047.8	571.7	1,069.1	406.9
1982	627.6	272.8	256.5	98.3	2,106.5	556.1	1,112.3	438.2
1983	395.4	159.0	187.4	49.0	2,198.2	624.9	1,106.0	467.4
1984	418.1	142.9	212.4	32.7	2,345.4	622.0	1,206.3	517.1
1985	738.1	193.7	271.5	272.5	2,540.0	672.9	1,267.7	599.4
1986	624.4	197.8	325.5	101.0	2,654.3	646.5	1,301.8	705.9

	Petroleum and coal products							
	Capital expenditures				Operating costs			
Year	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	321.8	222.5	96.1	3.2	337.8	192.5	125.4	19.9
1974	462.3	341.3	119.7	1.3	420.1	238.3	153.3	28.5
1975	555.7	398.2	155.7	1.7	563.1	339.4	192.1	31.7
1976	441.4	236.5	199.8	5.2	774.8	466.1	263.3	45.3
1977	368.5	167.7	195.6	5.3	948.0	601.3	289.3	57.4
1978	419.3	311.2	100.5	7.6	997.4	636.4	304.1	57.0
1979	534.3	397.8	119.4	17.1	1,173.8	750.7	370.8	25.3
1980	531.9	402.3	114.2	15.4	1,418.0	910.1	406.9	101.0
1981	590.6	440.8	131.7	18.2	1,685.5	1,118.0	437.2	130.2
1982	712.1	533.2	165.7	13.1	1,800.8	1,195.1	472.0	133.7
1983	485.0	308.2	164.7	12.0	1,893.7	1,203.6	552.3	137.9
1984	311.7	195.1	96.8	19.8	2,083.5	1,327.9	583.8	171.1
1985	290.4	175.0	88.4	27.0	2,063.4	1,278.5	586.5	198.5
1986	424.3	273.6	121.5	29.2	2,005.2	1,230.9	578.0	196.4

continued

Table 9 (continued)

Year	Rubber and miscellaneous plastic products							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	24.2	13.5	7.3	3.3	42.6	12.2	10.1	20.4
1974	37.9	22.2	13.5	2.2	58.8	15.7	15.1	28.2
1975	31.9	22.2	6.6	3.1	64.8	20.7	18.4	25.7
1976	37.4	24.2	10.0	3.1	80.3	22.3	24.0	34.0
1977	36.6	17.4	13.8	5.4	73.8	19.8	18.9	35.1
1978	27.7	18.7	5.5	3.4	84.9	17.7	23.9	43.3
1979	25.1	12.9	9.3	2.9	111.7	32.2	29.6	49.9
1980	21.7	12.6	6.9	2.3	108.2	30.4	27.6	50.2
1981	21.8	15.3	5.9	6.5	118.3	29.8	29.4	58.8
1982	25.2	14.8	7.7	2.7	90.2	22.2	28.2	39.8
1983	23.6	12.0	3.8	7.8	165.8	50.9	52.8	62.0
1984	33.4	20.5	7.0	5.8	168.0	51.1	48.7	68.1
1985	29.7	21.3	3.2	5.2	193.1	46.7	55.6	90.8
1986	36.0	20.1	9.7	6.2	226.2	50.9	52.0	123.3

Year	Stone, clay, and glass products							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	150.7	131.6	14.4	4.7	117.0	73.7	16.4	27.0
1974	208.8	185.8	13.1	10.0	152.9	98.7	24.7	29.4
1975	173.5	152.7	16.7	4.1	171.8	109.7	28.3	33.8
1976	104.7	82.2	18.9	3.6	192.1	122.8	30.3	39.0
1977	133.4	85.8	39.1	8.6	214.5	141.7	28.0	44.5
1978	123.8	98.1	28.0	3.7	251.1	163.7	33.2	54.2
1979	145.6	110.2	25.4	10.0	293.6	188.0	45.1	60.5
1980	1,510.0	123.1	17.9	10.0	301.7	1,821.1	48.2	71.4
1981	188.5	165.5	13.8	9.2	310.7	191.0	47.3	72.5
1982	105.2	84.9	14.0	6.3	260.2	142.8	44.0	39.8
1983	95.9	57.9	9.8	28.2	320.4	179.9	55.8	84.6
1984	84.0	65.6	13.1	5.2	377.9	215.0	64.2	98.7
1985	61.9	44.4	9.9	7.5	393.2	217.2	66.7	109.3
1986	84.4	53.1	13.7	17.6	423.6	237.0	68.2	118.3

continued

Table 9 (continued)

Year	Primary metal industries							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	498.6	397.2	84.7	16.8	466.8	264.7	148.3	53.8
1974	646.8	5.1	132.7	12.5	590.2	339.6	181.2	69.5
1975	833.5	640.6	187.5	5.4	715.2	429.9	209.4	75.9
1976	833.7	632.5	197.8	575.7	229.5	90.7	24.0	34.0
1977	874.6	616.0	250.2	8.4	1,122.3	721.6	268.3	132.3
1978	791.8	563.3	219.1	9.4	1,321.4	809.6	333.0	178.9
1979	823.1	588.8	227.3	6.9	1,587.2	981.7	442.0	163.5
1980	740.0	539.7	180.7	19.6	1,677.3	998.2	463.2	215.3
1981	728.2	567.2	144.1	16.9	1,911.8	1,111.9	549.2	250.7
1982	569.8	423.1	133.7	13.0	1,513.6	897.2	448.4	167.6
1983	225.3	147.6	100.2	7.5	1,615.6	904.3	454.6	256.7
1984	274.0	175.2	72.9	26.0	1,769.7	1017.3	450.7	301.7
1985	252.9	142.9	84.3	25.6	1,863.0	1067.0	517.4	278.7
1986	225.9	102.8	74.6	48.4	1,721.9	968.5	509.4	264.1

Year	Fabricated metal products							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	63.7	39.6	21.5	2.7	84.8	27.0	35.7	22.2
1974	90.5	56.4	28.2	5.9	110.1	34.5	44.9	30.7
1975	77.5	46.9	29.0	1.7	109.5	32.6	45.7	31.3
1976	72.9	35.5	34.1	3.4	124.3	35.4	52.7	36.1
1977	76.7	32.5	39.2	5.0	149.2	40.3	66.1	42.8
1978	61.6	33.1	26.2	2.3	168.7	42.1	73.8	52.8
1979	66.1	36.7	24.5	4.9	220.9	57.0	99.7	64.2
1980	76.4	37.5	34.8	4.2	219.2	49.0	88.2	81.9
1981	75.7	37.5	30.4	7.6	230.5	51.6	93.4	85.0
1982	95.9	57.9	43.3	6.7	223.5	48.6	103.4	71.5
1983	70.6	27.0	32.9	10.6	366.3	81.9	137.8	146.6
1984	125.3	25.2	82.5	17.6	348.5	64.9	128.2	155.4
1985	116.9	40.4	59.7	16.8	408.1	79.4	163.2	165.5
1986	135.8	36.7	80.9	18.2	502.5	95.6	187.7	219.2

continued

Table 9 (continued)

Year	Machinery, except electrical							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	56.3	36.6	15.6	4.1	72.5	19.7	23.0	29.9
1974	67.7	41.9	17.6	8.1	91.7	24.3	29.1	38.2
1975	60.5	37.5	20.8	2.3	98.0	28.4	33.7	36.0
1976	69.4	44.8	21.8	2.9	117.9	30.8	37.7	49.6
1977	90.2	42.3	42.4	5.5	135.4	33.1	49.8	52.6
1978	81.5	41.2	27.8	12.6	158.8	41.0	54.4	63.1
1979	84.5	38.5	38.2	7.8	200.2	50.1	69.0	81.1
1980	74.5	34.0	34.9	5.6	206.4	48.0	73.0	85.3
1981	67.1	30.9	28.0	8.2	220.9	47.3	81.6	91.7
1982	78.2	29.2	42.2	6.8	207.6	46.6	85.3	75.7
1983	51.0	17.7	19.0	14.3	290.5	58.0	105.0	127.5
1984	43.1	22.6	6.7	314.4	68.4	115.7	130.3	301.7
1985	69.0	21.2	35.1	12.7	344.0	76.0	119.9	147.7
1986	48.7	16.7	25.7	6.3	358.8	81.4	128.3	149.1

Year	Electric, electronic equipment							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	52.7	27.0	22.2	3.5	87.2	20.2	38.9	28.1
1974	55.6	24.6	28.0	3.1	88.6	22.7	39.8	26.2
1975	52.3	22.7	26.2	3.3	97.3	27.6	43.1	26.7
1976	58.4	23.0	31.3	4.1	109.9	26.8	50.8	32.3
1977	63.8	23.0	36.0	4.9	128.1	28.0	63.2	37.1
1978	72.2	32.9	36.0	3.3	148.6	30.7	71.7	46.1
1979	90.9	41.8	42.0	7.1	182.3	46.7	82.8	52.8
1980	79.0	43.5	27.1	8.4	205.0	45.2	87.8	71.9
1981	97.1	48.7	41.0	7.4	247.1	51.8	106.2	88.8
1982	105.9	58.1	40.9	6.9	260.2	55.1	116.6	88.7
1983	97.0	43.8	45.1	8.0	353.8	77.3	142.0	134.5
1984	112.4	38.3	59.5	14.6	364.0	74.6	150.3	139.1
1985	137.7	45.4	74.1	18.3	428.2	78.0	174.0	176.3
1986	125.1	46.6	61.5	17.0	530.8	88.3	210.9	231.5

continued

Table 9 (continued)

Year	Transportation equipment							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	101.2	52.6	41.7	6.9	129.8	35.2	51.1	43.4
1974	103.4	52.7	41.5	9.2	154.8	44.8	59.5	50.5
1975	75.4	32.1	36.4	6.8	168.3	52.2	66.4	49.7
1976	78.5	21.1	53.6	3.8	197.9	56.9	83.5	57.6
1977	82.6	36.9	39.4	6.3	233.9	60.6	97.3	76.1
1978	139.5	71.0	57.9	10.7	280.5	77.3	110.2	93.0
1979	189.5	120.1	59.5	99.9	331.8	96.4	126.3	109.1
1980	275.0	201.4	60.7	12.9	401.5	110.7	137.4	153.2
1981	283.3	209.2	60.0	14.2	426.1	117.5	150.7	157.7
1982	108.3	59.7	36.5	12.1	396.5	105.6	153.5	137.6
1983	98.3	33.0	55.0	10.2	560.3	157.5	224.2	178.6
1984	207.6	71.3	116.9	19.4	685.6	192.9	280.1	212.6
1985	456.5	254.5	165.1	36.9	738.8	194.5	283.9	260.3
1986	541.1	432.4	81.8	26.8	839.0	195.7	338.5	304.9

Year	Instruments and related products							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	11.8	3.0	5.6	3.2	21.9	2.0	11.3	8.6
1974	15.7	3.6	6.7	5.5	34.1	4.9	15.0	14.3
1975	29.6	11.2	17.3	1.1	38.5	5.9	19.5	13.2
1976	32.3	10.9	12.2	9.3	45.7	8.7	22.3	14.8
1977	24.4	14.5	8.5	1.4	47.3	9.0	23.0	15.4
1978	16.9	6.8	9.5	0.6	55.8	7.3	26.9	21.6
1979	23.2	13.0	7.7	2.5	69.2	10.6	30.7	27.9
1980	27.2	11.3	12.7	3.2	77.1	11.3	33.7	32.1
1981	40.1	14.4	23.7	2.1	90.4	12.8	40.0	37.9
1982	30.0	18.7	9.8	1.4	80.2	12.9	33.9	33.3
1983	21.1	10.4	9.5	1.2	163.8	25.0	53.9	85.0
1984	23.7	10.9	11.1	1.7	161.9	23.6	67.3	70.8
1985	24.8	13.8	7.8	3.1	165.1	24.2	71.8	69.1
1986	18.8	10.8	5.1	2.9	164.4	19.9	78.6	66.0

continued

Table 9 (continued)

Year	Food and kindred products							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	196.7	77.6	104.8	14.3	203.1	39.1	110.4	53.6
1974	199.2	73.4	111.7	14.3	268.9	48.8	143.5	76.8
1975	180.9	75.6	93.9	11.4	294.2	53.2	153.7	87.7
1976	207.5	102.5	97.6	7.4	345.9	57.7	187.5	100.5
1977	183.9	67.9	103.6	12.5	357.1	56.2	211.6	89.5
1978	175.0	67.7	94.4	12.9	412.0	69.4	243.2	99.4
1979	182.7	57.9	111.1	13.6	504.2	91.0	297.9	115.3
1980	208.2	61.7	133.0	13.5	519.4	81.6	314.3	123.6
1981	173.5	53.9	104.8	14.8	579.1	78.3	343.3	157.5
1982	169.3	47.4	110.9	11.0	522.1	77.1	328.1	116.2
1983	153.8	37.7	105.1	10.9	649.6	96.1	402.3	151.3
1984	154.5	50.6	91.8	12.2	714.4	101.3	458.1	155.0
1985	155.1	66.2	77.4	11.7	832.1	106.3	525.2	201.0
1986	185.8	61.9	108.2	15.7	932.1	126.0	559.9	246.1

Year	Textile mill products							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	29.2	10.3	17.7	1.2	38.8	6.3	23.5	9.0
1974	32.0	12.7	17.7	1.7	54.0	9.4	31.3	13.3
1975	43.0	19.7	22.2	1.1	50.7	9.4	29.4	12.0
1976	53.3	9.2	42.6	1.6	65.3	9.2	41.8	14.3
1977	36.7	20.7	14.7	1.4	75.0	10.9	46.4	-31.0
1978	59.7	42.7	15.4	1.6	92.5	19.0	51.6	21.9
1979	39.2	21.9	15.2	2.1	101.7	19.0	60.2	22.5
1980	59.5	32.5	23.6	3.5	115.8	16.6	59.3	39.9
1981	48.0	27.2	16.2	4.6	108.5	18.9	60.2	29.4
1982	22.0	12.2	6.2	3.6	74.7	14.8	41.4	18.3
1983	18.7	9.4	8.4	0.9	101.1	21.3	54.5	25.4
1984	20.9	12.8	6.3	1.8	122.2	25.8	68.4	28.0
1985	24.7	12.2	10.3	2.1	148.9	30.9	82.6	35.4
1986	25.5	12.3	10.5	2.6	161.6	28.5	94.9	38.2

continued

Table 9 (continued)

Year	Lumber and wood products							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	62.7	41.5	11.7	9.6	61.6	14.9	18.5	28.2
1974	81.1	58.4	7.6	15.0	64.2	19.5	14.0	30.8
1975	75.1	46.4	7.7	21.0	70.5	22.7	19.6	28.3
1976	51.1	29.5	9.2	12.5	81.3	26.6	21.1	33.6
1977	59.9	33.9	19.1	6.9	73.4	20.4	19.2	33.9
1978	84.5	46.9	25.6	12.0	90.7	27.7	19.4	43.7
1979	93.6	67.5	12.3	13.8	115.4	40.2	25.5	49.7
1980	81.5	55.8	15.6	10.1	129.1	39.6	32.9	56.4
1981	78.5	49.2	10.5	18.8	134.7	43.2	26.9	64.6
1982	33.2	20.0	11.7	1.5	87.1	26.4	23.4	37.3
1983	25.2	18.0	4.0	3.2	102.8	31.1	27.8	43.9
1984	48.5	24.1	18.8	5.7	114.2	41.2	30.7	42.4
1985	34.5	15.2	6.3	13.0	139.1	41.8	35.3	62.0
1986	33.3	17.8	11.0	4.6	178.9	61.7	42.6	74.7

Year	Paper and allied products							
	Capital expenditures				Operating costs			
	Total	Air	Water	Solid waste	Total	Air	Water	Solid waste
1973	339.6	166.4	161	12.1	220.5	59.2	118.1	43.2
1974	476.9	270.8	193.2	12.9	289.0	81.2	152.0	55.7
1975	605.3	323.0	266.0	16.3	344.0	100.9	185.5	57.5
1976	486.6	180.6	278.6	27.3	430.3	123.3	239.1	67.3
1977	427.4	134.1	261.7	31.6	529.0	133.5	309.0	86.4
1978	341.6	123.9	189.0	28.7	622.0	158.4	357.6	105.6
1979	426.4	207.0	180.6	38.8	698.2	176.6	400.5	121.1
1980	339.6	197.4	111.2	31.0	762.1	196.2	436.7	129.1
1981	285.5	168.0	86.5	31.1	829.7	211.8	469.9	148.0
1982	313.4	190.0	93.7	29.7	796.0	206.7	455.2	0.0
1983	216.1	122.3	65.9	27.9	919.1	226.5	508.9	183.6
1984	262.3	151.9	68.2	42.1	1,060.1	280.7	566.1	213.2
1985	332.4	190.9	106.0	35.6	1,120.8	313.0	573.4	234.4
1986	271.3	137.1	96.9	37.3	1,154.6	319.2	565.7	269.7

Source: U.S. Department of Commerce, Bureau of the Census. Pollution abatement costs and expenditures, annual. Current industrial reports, MA-200. Washington, D.C.

Notes: Statistics cover manufacturing establishments with 20 employees or more. Capital expenditures are new capital expenditures for pollution abatement. Operating costs are related to pollution abatement activities (including payments to government for the costs of pollution removal). Totals may not agree because of independent rounding.

Table 10
Environmental Impact Statements filed, by agency, 1979-1989

Federal Agencies	Year										
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Agriculture	172	104	102	89	59	65	117	118	75	68	101
Commerce	54	53	36	25	14	24	10	8	9	3	5
Defense	1	1	1	1	1	0	0	0	2	4	1
Air Force	8	3	7	4	6	5	7	8	9	3	12
Army	40	9	14	3	6	5	5	2	10	3	11
COE	182	150	186	127	119	116	106	91	76	69	47
Navy	11	9	10	6	4	9	8	13	9	6	4
Energy	28	45	21	24	19	14	4	13	11	16	12
EPA	84	71	96	63	67	42	16	18	19	23	24
GSA	13	11	13	8	1	0	4	0	1	3	0
HUD	170	140	140	93	42	13	15	18	6	0	2
ICC	8	5	2	2	2	1	2	1	2	0	0
Interior	126	131	107	127	146	115	105	98	110	120	65
NRC	19	17	47	31	11	11	8	4	3	2	3
Transportation	277	189	221	183	169	147	126	110	101	91	77
TVA	9	6	4	-	2	1	0	1	0	0	0
Other	71	22	26	22	9	9	16	18	12	17	28
Total	1,273	966	1,033	808	677	577	549	521	455	428	392

Source: U.S. Environmental Protection Agency, Office of Federal Activities, unpublished data. Washington, D.C.

Notes: Years refer to calendar years. Number of Environmental Impact Statements (EISs) includes draft EISs, EIS supplements, and Final EISs filed during the specified year. Some proposed projects may have several draft and final EISs filed over a period of years. HUD=Department of Housing and Urban Development. EPA=U.S. Environmental Protection Agency. GSA=General Services Administration. ICC=Interstate Commerce Commission. NRC=Nuclear Regulatory Commission. TVA=Tennessee Valley Authority.

Table 11
U.S. mine ore and waste production, 1960-1987

(billion metric tons)

Year	Metal crude ore	Metal waste	Nonmetal crude ore	Nonmetal waste
1960	0.382	0.468	1.461	0.214
1961	0.384	0.383	1.506	0.172
1962	0.383	0.400	1.497	0.204
1963	0.390	0.426	1.551	0.239
1964	0.415	0.419	1.633	0.253
1965	0.433	0.464	1.751	0.271
1966	0.454	0.582	1.823	0.336
1967	0.387	0.568	1.805	0.365
1968	0.436	0.662	1.769	0.377
1969	0.490	0.865	1.887	0.342
1970	0.532	0.885	1.896	0.395
1971	0.508	0.925	1.860	0.406
1972	0.523	0.980	1.905	0.381
1973	0.594	1.170	2.105	0.380
1974	0.569	1.107	2.087	0.384
1975	0.552	1.070	1.805	0.343
1976	0.586	1.143	1.887	0.362
1977	0.512	0.953	1.996	0.434
1978	0.570	0.925	2.186	0.519
1979	0.611	1.234	2.214	0.535
1980	0.542	1.080	1.941	0.562
1981	0.611	0.971	1.107	0.535
1982	0.391	0.625	0.816	0.334
1983	0.387	0.512	1.025	0.141
1984	0.432	0.566	0.998	0.260
1985	0.416	0.461	1.198	0.410
1986	0.426	0.564	1.052	0.345
1987	0.483p	0.754p	1.370p	1.161p

Source: U.S. Department of the Interior, Bureau of Mines. Minerals Yearbook, annual. Washington, D.C.

Note: p=preliminary.

Table 12
Surface mining reclamation, 1965-1986

(acres)

Year	Total land reclaimed	Year	Total land reclaimed
1965-1972	676,500	1981	129,746
1972-1974	52,300	1982	198,351
1974-1977	22,203	1983	172,528
1978	47,106	1984	239,285
1979	105,135	1985	201,718
1980	126,917	1986	168,592

Source: 1965-1977: U.S. Department of Agriculture, Soil Conservation Service. 1979. The status of land disturbed by mining in the United States: Basic statistics by State and County as of July 1977, pp. 3,4,11. Washington, D.C.

1978-1986: U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement. 1987. Surface coal mining reclamation: 10 years of progress, 1977-1987, table 3, pp. 44-45. Washington, D.C.

U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement. 1987. The abandoned mine program: 1977-1987, p. 25. Washington, D.C.

Notes: Data for 1965-1986 are not strictly comparable because of different methods of data collection. Data for 1965-1977 refer to reclamation of surface coal, sand and gravel, and other mined areas and were compiled from national inventories. Data for 1978-1986 refer to acreages of surface coal mined areas released from reclamation bonds after reclamation was completed. In addition to data reported above, 5,600 abandoned mine sites, encompassing 55,615 acres across the Nation, have been reclaimed since 1977.

Table 13
U.S. energy production, by source, 1950-1990

(Quadrillion Btu)

Year	Coal	Natural gas	Crude oil & NGPL	Hydro-electric	Nuclear	Other	Total
1950	14.06	6.23	12.27	1.42	0.00	0.010	33.98
1955	12.37	9.34	15.65	1.36	0.00	<0.005	38.73
1960	10.82	12.66	16.39	1.61	0.01	<0.005	41.49
1961	10.45	13.10	16.76	1.66	0.02	<0.005	41.99
1962	10.90	13.72	17.11	1.82	0.03	<0.005	43.58
1963	11.85	14.51	17.68	1.77	0.04	<0.005	45.85
1964	12.52	15.30	17.96	1.89	0.04	<0.005	47.72
1965	13.06	15.78	18.40	2.06	0.04	<0.005	49.34
1966	13.47	17.01	19.56	2.06	0.06	<0.005	52.17
1967	13.83	17.94	20.83	2.35	0.09	0.010	55.04
1968	13.61	19.07	21.63	2.35	0.14	0.010	56.81
1969	13.86	20.45	21.98	2.65	0.15	0.010	59.10
1970	14.61	21.67	22.91	2.63	0.24	0.010	62.07
1971	13.19	22.28	22.57	2.82	0.41	0.010	61.29
1972	14.09	22.21	22.64	2.86	0.58	0.030	62.42
1973	13.99	22.19	22.06	2.86	0.91	0.040	62.06
1974	14.07	21.21	21.04	3.18	1.27	0.050	60.84
1975	14.99	19.64	20.10	3.15	1.90	0.070	59.86
1976	15.65	19.48	19.59	2.98	2.11	0.080	59.89
1977	15.76	19.57	19.78	2.33	2.70	0.090	60.22
1978	14.91	19.49	20.68	2.94	3.02	0.060	61.10
1979	17.54	20.08	20.39	2.93	2.78	0.090	63.80
1980	18.60	19.91	20.50	2.90	2.74	0.110	64.76
1981	18.38	19.70	20.46	2.76	3.01	0.120	64.42
1982	18.64	18.25	20.50	3.27	3.13	0.100	63.89
1983	17.25	16.53	20.57	3.53	3.20	0.130	61.19
1984	19.72	17.93	21.12	3.35	3.55	0.170	65.81
1985	19.33	16.91	21.23	2.94	4.15	0.210	64.76
1986	19.51	16.47	20.53	3.02	4.47	0.230	64.25
1987	20.12	16.87	19.82	2.59	4.92	0.250	64.55
1988	20.94	17.19	19.52	2.32	5.68	0.240	65.88
1990	21.60p	17.80p	17.90p	na	5.90p	na	69.90p

Source: U.S. Department of Energy, Energy Information Administration. 1989. Annual energy review 1988, table 2, p. 9. DOE/EIA-0384(88). Washington, D.C.

U.S. Department of Energy, Energy Information Administration. 1990. Annual energy outlook 1990 with projections to 2010, table A2, p. 41. DOE/EIA-0383(90). Washington, D.C.

Notes: NGPL= Natural gas plant liquids. Other includes electricity produced from geothermal, wood, waste, wind, photovoltaic, and solar thermal sources. p=projected. na=not available.

Table 14
U.S. coal production, by rank and source, 1900-1988

(million metric tons)

	Rank				Source	
Year	Bituminous	Sub-bituminous	Lignite	Anthracite	Under-ground	Surface
1900	192.57	0.00	0.00	52.03	0.00	0.00
1905	285.76	0.00	0.00	70.44	0.00	0.00
1910	378.32	0.00	0.00	76.63	0.00	0.00
1915	401.46	0.00	0.00	80.72	475.04	0.00
1920	515.78	0.00	0.00	81.27	580.72	9.90
1925	471.69	0.00	0.00	56.07	508.22	16.73
1930	424.05	0.00	0.00	62.93	464.94	20.30
1935	337.74	0.00	0.00	47.31	356.01	26.18
1940	417.92	0.00	0.00	46.70	416.42	44.91
1945	523.90	0.00	0.00	49.83	455.78	108.88
1950	468.29	i	i	39.98	381.85	126.42
1955	421.42	i	i	23.77	324.67	120.52
1960	376.87	i	i	17.07	265.37	128.56
1965	464.46	i	i	13.48	306.53	171.42
1970	524.67	14.90	7.29	8.82	308.86	246.82
1975	523.81	46.35	17.97	5.63	266.17	327.58
1980	570.29	133.98	42.77	5.49	306.12	446.42
1985	556.92	174.82	65.68	4.26	318.24	483.35
1988	583.11	199.26	77.49	3.15	344.34	518.67

Source: Bureau of the Census. 1976. Historical statistics of the United States: Colonial times to 1970, series M 93, 94, 95, 123, 124, 125. Washington, D.C.

U.S. Department of Energy, Energy Information Administration. 1989. Annual energy review 1988, table 77, p. 179. DOE/EIA-0384(88). Washington, D.C.

Note: i=included in bituminous coal.

Table 15
U.S. petroleum production, 1940-1990

(million barrels per day)

Year	Crude oil	Natural gas plant liquids	Year	Crude oil	Natural gas plant liquids
1940	3.707	0.153	1966	8.295	1.284
1941	3.842	0.222	1967	8.810	1.409
1942	3.799	0.227	1968	9.121	1.508
1943	4.125	0.241	1969	9.238	1.590
1944	4.597	0.274	1970	9.637	1.660
1945	4.695	0.307	1971	9.463	1.693
1946	4.751	0.318	1972	9.467	1.749
1947	5.088	0.362	1973	9.208	1.738
1948	5.535	0.403	1974	8.774	1.688
1949	5.046	0.430	1975	8.375	1.633
1950	5.407	0.499	1976	8.154	1.608
1951	6.158	0.561	1977	8.245	1.618
1952	6.274	0.612	1978	8.707	1.567
1953	6.458	0.654	1979	8.552	1.584
1954	6.342	0.691	1980	8.600	1.577
1955	6.807	0.771	1981	8.572	1.609
1956	7.171	0.802	1982	8.649	1.550
1957	7.170	0.808	1983	8.688	1.559
1958	6.710	0.808	1984	8.880	1.634
1959	7.054	0.879	1985	8.970	1.610
1960	7.055	0.932	1986	8.680	1.550
1961	7.183	0.991	1987	8.350	1.600
1962	7.332	1.021	1988	8.130	1.620
1963	7.542	1.098	1989	7.670p	1.600p
1964	7.635	1.157	1990	7.370p	1.620p
1965	7.804	1.210			

Source: Bureau of the Census. 1976. Historical statistics of the United States: Colonial times to 1970, series M 143, 138. Washington, D.C.

U.S. Department of Energy, Energy Information Administration. 1989. Annual energy review 1988, table 48, p. 113. DOE/EIA-0384(88). Washington, D.C.

U.S. Department of Energy, Energy Information Administration. 1990. Annual energy outlook 1990 with projections to 2010, table A3, p. 42. DOE/EIA-0383(90). Washington, D.C.

Notes: Crude oil includes lease condensate. p=projected.

Table 16
U.S. natural gas production, 1900-1990

(trillion cubic feet)

Year	Well production	Year	Well production	Year	Well production
1900	0.128	1931	1.722	1962	13.880
1901	0.180	1932	1.594	1963	14.750
1902	0.206	1933	1.597	1964	15.550
1903	0.239	1934	1.816	1965	16.040
1904	0.257	1935	1.969	1966	17.207
1905	0.320	1936	2.225	1967	18.171
1906	0.389	1937	2.473	1968	19.322
1907	0.407	1938	2.358	1969	20.698
1908	0.402	1939	2.538	1970	21.921
1909	0.481	1940	2.734	1971	22.490
1910	0.509	1941	2.894	1972	22.530
1911	0.513	1942	3.146	1973	22.650
1912	0.562	1943	3.516	1974	21.600
1913	0.582	1944	3.815	1975	20.110
1914	0.592	1945	4.042	1976	19.950
1915	0.629	1946	4.153	1977	20.030
1916	0.753	1947	4.582	1978	19.970
1917	0.795	1948	5.148	1979	20.470
1918	0.721	1949	5.420	1980	20.180
1919	0.746	1950	6.282	1981	19.960
1920	0.812	1951	7.457	1982	18.520
1921	0.674	1952	8.013	1983	16.820
1922	0.776	1953	8.397	1984	18.230
1923	1.025	1954	8.743	1985	17.200
1924	1.162	1955	9.405	1986	16.790
1925	1.210	1956	10.082	1987	17.350
1926	1.336	1957	10.680	1988	17.490
1927	1.471	1958	11.030	1989	16.910p
1928	1.596	1959	12.046	1990	17.250p
1929	1.952	1960	12.771		
1930	1.979	1961	13.250		

Source: Bureau of the Census. 1976. Historical statistics of the United States: Colonial times to 1970, series M 147. Washington, D.C.

U.S. Department of Energy, Energy Information Administration. 1989. Annual energy review 1988, table 69, p. 159. DOE/EIA-0384(88). Washington, D.C.

U.S. Department of Energy, Energy Information Administration. 1990. Annual energy outlook 1990 with projections to 2010, table A4, p. 43. DOE/EIA-0383(90). Washington, D.C.

Notes: Production data are for marketed production which includes extraction loss and transfers to natural gas plant liquids. p=projected.

Table 17
U.S. production of electricity, by energy source, 1950-1990

(billion kilowatthours)

Year	Coal	Natural gas	Petro-leum	Nuclear power	Hydro-electric	Geo-thermal & other	Total
1950	155	45	34	0	96	<1	329
1955	301	95	37	0	113	<1	547
1960	403	158	48	1	146	<1	756
1961	422	169	49	2	152	<1	794
1962	450	184	49	2	169	<1	855
1963	494	202	52	3	166	<1	917
1964	526	220	57	3	177	<1	984
1965	571	222	65	4	194	<1	1,055
1966	613	251	79	6	195	1	1,144
1967	630	265	89	8	222	1	1,214
1968	685	304	104	13	222	1	1,329
1969	706	333	138	14	250	1	1,442
1970	704	373	184	22	248	1	1,532
1971	713	374	220	38	266	1	1,613
1972	771	376	274	54	273	2	1,750
1973	848	341	314	83	272	2	1,861
1974	828	320	301	114	301	3	1,867
1975	853	300	289	173	300	3	1,918
1976	944	295	320	191	284	4	2,038
1977	985	306	358	251	220	4	2,124
1978	976	305	365	276	280	3	2,206
1979	1,075	329	304	255	280	4	2,247
1980	1,162	346	246	251	276	6	2,286
1981	1,203	346	206	273	261	6	2,295
1982	1,192	305	147	283	309	5	2,241
1983	1,259	274	144	294	332	6	2,310
1984	1,342	297	120	328	321	9	2,416
1985	1,402	292	100	384	281	11	2,470
1986	1,386	249	137	414	291	12	2,487
1987	1,464	273	118	455	250	12	2,572
1988	1,537	253	149	527	223	12	2,701
1989	1,532p	254p	151p	521p	291p	i	2,795p
1990	1,561p	249p	130p	550p	315p	i	2,795p

Source: U.S. Department of Energy, Energy Information Administration. 1989. Annual energy review 1988, table 85, p. 199. DOE/EIA/038(88). Washington, D.C.

U.S. Department of Energy, Energy Information Administration. 1990. Annual energy outlook 1990 with projections to 2010, table A6, p. 45. DOE/EIA-0383(90). Washington, D.C.

Notes: Other includes wood, waste, photovoltaic, and solar thermal energy. p=projected. i=included under hydroelectric.

Table 18
Nuclear generating units, 1957-1988

(operable units at end of year)

Year	Units	Year	Units
1957	1	1973	39
1958	1	1974	48
1959	1	1975	54
1960	3	1976	61
1961	3	1977	65
1962	5	1978	70
1963	6	1979	68
1964	6	1980	70
1965	6	1981	74
1966	8	1982	77
1967	10	1983	80
1968	11	1984	86
1969	14	1985	95
1970	18	1986	100
1971	21	1987	107
1972	29	1988	108

Source: 1957-1972: Federal Power Commission, Form 4, "Monthly Power Plant Report." Washington, D.C.

1973-1988: Nuclear Regulatory Commission, Report NUREG-0020, Licensed Operating Reactors, monthly. Washington, D.C.

Table 19
Annual accumulated volume of uranium mill tailings, 1978-1990

(million cubic meters)

Year	Accumulation	Year	Accumulation
Prior to 1978	68.0	1984	113.6
1978	75.8	1985	114.6
1979	84.9	1986	115.4
1980	94.4	1987	116.2
1981	102.7	1988	116.9
1982	107.7	1989	117.3p
1983	111.1	1990	117.5p

Source: U.S. Department of Energy. 1989. Integrated data base for 1990: Spent fuel and radioactive waste inventories, projections, and characteristics, table 5-1, p. 133. Washington, D.C.

Table 20
Annual accumulated mass and radioactivity of permanently discharged spent fuel from nuclear reactors, 1968-1990

Year	Mass (1,000 mtihm)	Radio-activity (billion curies)	Year	Mass (1,000 mtihm)	Radio-activity (billion curies)	Year	Mass (1,000 mtihm)	Radio-activity (billion curies)
1968	0.001	0.001	1976	2.251	4.457	1984	11.255	13.134
1969	0.010	0.039	1977	3.091	5.751	1985	12.607	14.052
1970	0.055	0.215	1978	4.171	7.811	1986	14.102	15.475
1971	0.145	0.391	1979	5.290	8.958	1987	15.896	17.769
1972	0.405	1.178	1980	6.534	10.159	1988	17.607	18.654
1973	0.567	1.024	1981	7.679	10.614	1989	19.600p	21.000p
1974	1.019	2.366	1982	8.689	10.480	1990	21.400p	21.400p
1975	1.556	3.273	1983	9.945	12.073			

Source: U.S. Department of Energy. 1989. Integrated data base for 1989: Spent fuel and radioactive waste inventories, projections, and characteristics, table 1.4, p. 31. Washington, D.C.

Notes: Estimates represent a conservative upper limit of spent fuel projections (i.e., lower reference case). mtihm=metric tons initial heavy metal. p=projected.

Table 21
Annual accumulated volume and radioactivity of low-level and high-level nuclear waste, 1980-1990

	Low-level waste				High-level waste			
	DOE/defense		Commercial		DOE/defense		Commercial	
Year	Volume (1,000 m3)	Radio-activity (million curies)	Volume (1,000 m3)	Radio-activity (million curies)	Volume (million m3)	Radio-activity (billion curies)	Volume (1,000 m3)	Radio-activity (million curies)
1980	1.95	9.25	0.77	4.55	0.30	1.31	2.20	35.00
1981	2.01	9.59	0.85	4.48	0.31	1.58	2.20	34.20
1982	2.10	10.64	0.93	4.57	0.34	1.32	2.20	33.40
1983	2.19	11.22	1.00	4.73	0.35	1.25	2.20	32.70
1984	2.28	12.28	1.08	4.95	0.36	1.40	2.20	31.90
1985	2.19	12.17	1.16	5.28	0.36	1.47	2.20	31.20
1986	2.28	12.02	1.21	5.06	0.36	1.41	2.20	30.40
1987	2.38	13.99	1.26	4.92	0.38	1.27	2.20	29.70
1988	2.47	13.42	1.30	4.79	0.38	1.17	2.10	29.30
1989	2.57p	13.88p	1.34p	4.87p	0.37p	1.13p	2.10p	28.30p
1990	2.73p	14.29p	1.37p	4.92p	0.38p	1.16p	1.60p	28.00p

Source: U.S. Department of Energy. 1989. Integrated data base for 1989: Spent fuel and radioactive waste inventories, projections, and characteristics, table 2.1, p. 47, table 4.1, p.109 & table 4.2, p. 109. Washington, D.C.

Notes: DOE = U.S. Department of Energy. defense=defense-related activities. m3=cubic meters. p=projected.

Table 22
Radiation levels in air and pasteurized milk, 1960-1989

(annual mean exposure in picocuries per liter)

Year	Krypton-85 in air	Strontium-90 in pasteurized milk	Cesium-137 in pasteurized milk
1960	na	8.6	18.0
1961	na	8.0	11.0
1962	7.5	13.4	44.0
1963	9.0	23.5	108.0
1964	9.5	23.8	109.0
1965	10.0	17.6	58.0
1966	11.0	13.3	29.0
1967	11.5	10.2	16.0
1968	12.5	8.9	11.0
1969	13.5	7.5	9.0
1970	15.4	7.3	8.0
1971	14.8	6.8	9.0
1972	14.9	5.6	6.0
1973	16.7	4.4	5.0
1974	17.0	4.7	8.0
1975	17.5	3.9	9.0
1976	16.5	3.5	7.0
1977	17.1	3.6	6.0
1978	na	3.8	7.3
1979	21.8	3.5	4.0
1980	na	2.8	6.8
1981	na	2.8	2.5
1982	26.4	2.8	4.1
1983	38.6	2.3	1.6
1984	na	2.1	2.1
1985	na	2.0	2.7
1986	na	1.9	5.5
1987	na	1.9	6.6
1988	na	1.6	4.0
1989	na	1.5	2.8

Source: U.S. Environmental Protection Agency, Office of Radiation Programs. Environmental radiation data report EPA-520/5, quarterly issues. Montgomery, AL.

Notes: Data for 1989 are for the first six months of the calendar year. na=not available.

Table 23
U.S. energy consumption, by source, 1950-1990

(Quadrillion Btu)

Year	Coal	Natural gas	Crude oil & NGPL	Hydro-electric	Nuclear	Other	Total
1950	12.35	5.97	13.32	1.44	0.00	0.010	33.08
1955	11.17	9.00	17.25	1.41	0.00	0.010	38.82
1960	9.84	12.39	19.92	1.66	0.01	<0.005	43.80
1965	11.58	15.77	23.25	2.06	0.04	<0.005	52.68
1966	12.14	17.00	24.40	2.07	0.06	<0.005	55.66
1967	11.91	17.94	25.28	2.34	0.09	0.000	57.57
1968	12.33	19.21	26.98	2.34	0.14	0.000	61.00
1969	12.38	20.68	28.34	2.66	0.15	0.020	64.19
1970	12.26	21.79	29.52	2.65	0.24	0.050	66.43
1971	11.60	22.47	30.56	2.86	0.41	0.020	67.89
1972	12.08	22.70	32.95	2.94	0.58	0.010	71.26
1973	12.97	22.51	34.84	3.01	0.91	0.040	74.28
1974	12.66	21.73	33.45	3.31	1.27	0.110	72.54
1975	12.66	19.95	32.73	3.22	1.90	0.090	70.55
1976	13.58	20.35	35.17	3.07	2.11	0.080	74.36
1977	13.92	19.93	37.12	2.51	2.70	0.100	76.29
1978	13.77	20.00	39.97	3.14	3.02	0.190	78.09
1979	15.04	20.67	37.12	3.14	2.78	0.150	78.90
1980	15.42	20.39	34.20	3.12	2.74	0.080	75.96
1981	15.91	19.93	31.93	3.11	3.01	0.110	73.99
1982	15.32	18.51	30.23	3.57	3.13	0.080	70.84
1983	15.89	17.36	30.05	3.90	3.20	0.120	70.50
1984	17.07	18.51	31.05	3.76	3.55	0.160	74.06
1985	17.48	17.83	30.92	3.36	4.15	0.200	73.94
1986	17.26	16.71	32.20	3.39	4.47	0.220	74.26
1987	18.01	17.67	32.87	3.07	4.91	0.250	76.77
1988	18.81	18.60	33.96	2.62	5.68	0.280	79.94
1989	19.00p	18.90p	34.10p	na	5.60p	na	84.20p
1990	19.00p	19.20p	34.40p	na	5.90p	na	85.40p

Source: U.S. Department of Energy, Energy Information Administration. 1989. Annual energy review 1988, table3, p. 11. DOE/EIA-0384(88). Washington, D.C.

U.S. Department of Energy, Energy Information Administration. 1990. Annual energy outlook 1990 with projections to 2010, table A2, p. 41. DOE/EIA-0383(90). Washington, D.C.

Notes: NGPL= Natural gas plant liquids. Other includes electricity produced from geothermal, wood, waste, wind, photovoltaic, and solar thermal sources. p=projected. na=not available, but included in total.

Table 24
U.S. energy consumption, by end use sector, 1950-1990

(Quadrillion Btu)

Year	Fossil fuels			Electric utilities	Total
	Residential & Commercial	Industrial	Transportation		
1950	6.65	13.28	8.38	4.70	33.08
1955	7.39	15.42	9.48	6.50	38.82
1960	8.75	16.26	10.56	8.19	43.80
1965	10.00	19.25	12.39	11.01	52.68
1966	10.47	20.11	13.05	11.99	55.66
1967	11.04	20.10	13.70	12.70	57.57
1968	11.40	20.87	14.81	13.88	61.00
1969	11.90	21.63	15.45	15.18	64.19
1970	12.14	21.94	16.04	16.27	66.43
1971	12.35	21.68	16.67	17.15	67.89
1972	12.64	22.40	17.67	18.52	71.26
1973	12.27	23.55	18.57	19.85	74.28
1974	11.77	22.63	18.08	20.02	72.54
1975	11.60	20.37	18.20	20.35	70.55
1976	12.25	21.44	19.06	21.57	74.36
1977	11.87	21.89	19.77	22.71	76.29
1978	11.91	21.86	20.56	23.72	78.09
1979	11.53	22.78	20.43	24.13	78.90
1980	10.72	21.04	19.66	24.50	75.96
1981	10.04	19.69	19.46	24.76	73.99
1982	10.06	17.45	19.03	24.26	70.84
1983	9.71	16.72	19.10	24.93	70.50
1984	10.09	18.16	19.84	25.94	74.06
1985	9.83	17.53	20.08	26.48	73.94
1986	9.58	17.25	20.74	26.66	74.26
1987	9.72	18.13	21.34	27.55	76.77
1988	10.42	19.06	21.81	28.62	79.94
1989	11.17p	21.75p	22.01p	29.27p	84.20p
1990	11.35p	22.20p	22.36p	29.49p	85.40p

Source: U.S. Department of Energy, Energy Information Administration. 1989. Annual energy review 1988, table 4, p. 13. DOE/EIA-0384(88). Washington, D.C.

U.S. Department of Energy, Energy Information Administration. 1990. Annual energy outlook 1990 with projections to 2010, table A2, p. 41; table A8, p.47; table A9, p. 48; table A10, p. 49; and table A11, p. 50. DOE/EIA-0383(90). Washington, D.C.

Notes: Does not include wood, geothermal, waste, photovoltaic, or solar energy, except that used by electric utilities. Totals may not equal due to independent rounding. p=projected.

Table 25
Automobile travel and fuel economy, 1970-1987

Year	Automobiles in use (millions)	Miles traveled per automobile (thousand)	Automobile fuel consumption rate (mpg)	Automobile fuel economy standard (mpg)
1970	89.2	10.27	13.5	na
1973	102.0	10.26	13.3	na
1974	104.8	9.61	13.4	na
1975	106.7	9.69	13.5	na
1976	110.2	9.79	13.5	na
1977	112.3	9.88	13.8	na
1978	116.6	9.84	14.0	na
1979	118.5	9.40	14.4	na
1980	121.6	9.14	15.5	20.0
1981	123.1	9.19	15.9	22.0
1982	123.7	9.43	16.7	24.0
1983	126.2	9.48	17.1	26.0
1984	128.1	9.56	17.8	27.0
1985	131.9	9.56	18.2	27.5
1986	135.4	9.61	18.3	26.0
1987	139.0	9.88	19.2	26.0

Source: U.S. Department of Transportation, Federal Highway Administration. Highway statistics annual, table VM-1. Washington, D.C.

U.S. Department of Energy, Oak Ridge National Laboratory. 1988. Transportation energy conservation data book (draft). Oak Ridge, TN.

Notes: mpg=miles per gallon. na=not available.

Table 26
Offstream water use, by source and end user, 1900-1985

(billions of gallons per day)

	Source		End user				
Year	Ground water	Surface water	Public supply	Rural & domestic livestock	Irrigation	Thermo-electric utility	Other industries
1900	na	na	3.0	2.0	20.0	5.0	10.0
1910	na	na	5.0	2.2	39.0	7.0	14.0
1920	na	na	6.0	2.4	56.0	9.0	18.0
1930	na	na	8.0	2.9	60.0	18.0	21.0
1940	na	na	10.0	3.1	71.0	23.0	29.0
1945	na	na	12.0	3.4	80.0	31.5	35.0
1950	34.0	150.0	14.0	3.6	89.0	40.0	37.0
1955	47.6	198.0	17.0	3.6	110.0	72.0	39.0
1960	50.4	221.0	21.0	3.6	110.0	100.0	38.0
1965	60.5	253.0	24.0	4.0	120.0	130.0	46.0
1970	69.0	303.0	27.0	4.5	130.0	170.0	47.0
1975	83.0	329.0	29.0	4.9	140.0	200.0	45.0
1980	83.9	361.0	34.0	5.6	150.0	210.0	45.0
1985	73.7	320.0	37.0	7.8	140.0	190.0	31.0

Source: U.S. Department of Commerce, Bureau of the Census. 1976. Historical statistics of the United States, series J 92-103. Washington, D.C.

Solley, W.B., C.F. Merk & R.R. Pierce. 1988. Estimated use of water in the United States in 1985. U.S. Department of the Interior, Geological Survey Circular 1004, p. 69.

Note: na=not available.

Table 27
Population served by municipal wastewater treatment systems, by level of treatment, 1960-1988

(million people)

Level of treatment	1960	1978	1982	1986	1988
Not served	70.0	66.0	62.0	67.8	69.9
No discharge	na	na	na	5.7	6.1
Raw discharge	na	na	na	1.6	1.4
Less than secondary treatment	36.0	237.0	37.0	28.8	26.5
Secondary treatment	na	56.0	63.0	72.3	78.0
Greater than secondary treatment	4.0	49.0	53.0	54.9	65.7

Source: 1960: Kollar, K.L. 1979. Market for water and wastewater treatment equipment. J. Water Pollution Control Fed. 51:682.

1978-1988: U.S. Environmental Protection Agency, Office of Municipal Pollution Control. Needs survey to Congress--assessment of needed publicly owned wastewater treatment facilities in the United States, biennial. Washington, D.C.

Notes: Data for 1960 are not strictly comparable to other data because of different methods of data collection. na=not available.

Table 28
Estimated phosphorus loadings to the Great Lakes, 1976-1986

(metric tons)

Year	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
1976	3,550	6,656	4,802	18,480	12,695
1977	3,661	4,666	3,763	14,576	8,935
1978	5,990	6,245	5,255	19,431	9,547
1979	6,619	7,659	4,881	11,941	8,988
1980	6,412	6,574	5,307	14,855	8,579
1981	3,412	4,091	3,481	10,452	7,437
1982	3,160	4,084	4,689	12,349	8,891
1983	3,407	4,515	3,978	9,880	6,779
1984	3,642	3,611	3,452	12,874	7,948
1985	2,864	3,956	5,758	11,216	7,083
1986	3,059	4,981	4,210	11,118	9,561

Source: Great Lakes Water Quality Board. Great Lakes water quality, annual. Surveillance Subcommittee Report to the International Joint Commission, United States and Canada. Windsor, ON.

Note: The 1978 Great Lakes Water Quality Agreement set target loadings for each lake (in metric tons per year): Lake Superior-3,400; Lake Michigan-5,600; Lake Huron-4,360; Lake Erie-11,000; and Lake Ontario-7,000.

Table 29
Contaminant levels in coho salmon from the Great Lakes, 1980-1986

(parts per million in skin on fillets)

	Lake Michigan			Lake Erie		
Year	DDT	PCB	Dieldrin	DDT	PCB	Dieldrin
1980	0.62	1.93	0.06	0.16	1.07	0.04
1981	0.53	1.37	na	0.11	0.90	na
1982	0.27	0.83	0.02	0.10	0.67	0.02
1983	0.16	0.30	0.02	0.09	0.51	0.02
1984	0.19	0.39	0.01	0.06	0.38	0.01
1986	0.15	0.53	0.01	0.13	0.48	0.02

Source: DeVault, D.S., J.M. Clark, G. Lahois & J. Weishaar. 1988. Contaminants and and trends in fall run coho salmon. Journal of Great Lakes Research 14: 23-33.

Notes: DDT=Dichloro-diphenyl-trichloro ethane. PCB=Polychlorinated biphenyl.

Table 30
Contaminant levels in herring gull eggs from Great Lakes colonies, 1974-1989

(parts per million in whole egg samples, wet weight)

	Granite Island, Black Bay, Western Lake Superior					
Year	Perfat	DDE	Dieldrin	Mirex	HCB	PCB
1974	8.79	19.26	0.61	1.30	0.22	75.43
1975	8.16	24.16	0.44	0.62	0.12	82.02
1976	na	na	na	na	na	na
1977	9.23	11.83	0.35	0.24	0.12	54.91
1978	9.72	9.61	0.39	0.39	0.14	45.35
1979	9.24	6.39	0.64	0.19	0.15	59.05
1980	6.85	3.65	0.33	0.09	0.08	27.48
1981	8.44	5.23	0.38	0.09	0.09	31.33
1982	8.45	6.75	0.44	0.22	0.07	39.70
1983	na	na	na	na	na	na
1984	9.74	3.40	0.37	0.05	0.05	17.81
1985	9.40	3.30	0.28	0.09	0.06	19.51
1986	7.40	3.30	0.37	0.09	0.05	14.30
1987	8.90	2.90	0.26	0.03	0.04	13.00
1988	.9.0	3.20	0.31	0.03	0.05	16.00
1989	7.60	2.40	0.34	0.05	0.06	15.00

continued

Table 30 (continued)

Year	Agawa Rock, Eastern Lake Superior					
	Perfat	DDE	Dieldrin	Mirex	HCB	PCB
1974	8.68	14.19	0.42	0.76	0.29	50.07
1975	7.24	22.03	0.32	1.29	0.24	70.45
1976	na	na	na	na	na	na
1977	9.25	12.01	0.40	0.42	0.13	55.53
1978	9.26	9.68	0.40	0.15	0.09	36.85
1979	9.29	7.26	0.56	0.33	0.14	58.43
1980	8.32	3.70	0.35	0.17	0.08	23.68
1981	8.91	6.26	0.49	0.20	0.14	36.35
1982	8.90	5.83	0.34	0.51	0.10	29.78
1983	8.91	3.49	0.33	0.15	0.05	21.42
1984	9.30	2.49	0.34	0.19	0.06	16.01
1985	9.66	2.97	0.36	0.12	0.05	12.26
1986	7.80	3.13	0.32	0.12	0.05	13.90
1987	9.20	2.20	0.13	0.16	0.04	11.00
1988	9.60	2.70	0.37	0.09	0.05	11.00
1989	7.50	2.60	0.33	0.09	0.04	15.00

Year	Big Sister Island, Green Bay, Lake Michigan					
	Perfat	DDE	Dieldrin	Mirex	HCB	PCB
1976	8.90	33.40	0.82	0.36	0.14	120.00
1977	na	na	na	na	na	na
1978	9.12	21.80	0.90	0.26	0.12	89.98
1979	na	na	na	na	na	na
1980	8.31	11.38	0.65	0.07	0.08	56.95
1981	na	na	na	na	na	na
1982	8.94	17.89	0.75	0.07	0.07	66.89
1983	9.03	6.76	0.53	0.04	0.03	27.66
1984	9.02	9.34	0.64	0.13	0.06	34.00
1985	9.89	7.93	0.54	0.18	0.05	36.82
1986	10.00	7.05	0.28	0.05	0.07	27.00
1987	10.50	12.00	0.85	0.10	0.07	45.00
1988	7.70	4.00	0.55	0.03	0.03	17.00
1989	8.70	4.70	0.58	0.03	0.04	22.00

continued

Table 30 (continued)

	Gull Island, Northern Lake Michigan					
Year	Perfat	DDE	Dieldrin	Mirex	HCB	PCB
1976	na	na	na	na	na	na
1977	na	na	na	na	na	na
1978	9.73	22.91	0.83	0.16	0.12	91.49
1979	na	na	na	na	na	na
1980	8.47	12.95	0.75	0.14	0.10	58.70
1981	na	na	na	na	na	na
1982	9.21	13.84	0.88	0.11	0.12	63.93
1983	7.90	6.19	0.68	0.06	0.07	32.65
1984	9.47	6.37	0.41	0.06	0.06	28.93
1985	9.63	5.92	0.40	0.04	0.05	26.51
1986	7.90	7.91	0.49	0.09	0.08	27.50
1987	9.20	4.00	0.33	0.06	0.04	17.00
1988	9.30	6.10	0.55	0.04	0.06	22.00
1989	8.90	5.00	0.53	0.04	0.05	21.00

	Chantry Island, Southern Lake Huron					
Year	Perfat	DDE	Dieldrin	Mirex	HCB	PCB
1974	8.20	21.00	0.47	2.20	0.47	86.00
1975	8.61	11.85	0.31	0.48	0.18	39.33
1976	na	na	na	na	na	na
1977	9.44	13.32	0.57	0.33	0.17	63.66
1978	11.05	6.02	0.22	0.26	0.14	32.13
1979	7.72	2.54	0.28	0.20	0.10	31.08
1980	9.42	2.83	0.23	0.16	0.08	23.41
1981	9.23	4.08	0.25	0.35	0.07	27.70
1982	8.22	5.03	0.29	0.58	0.08	38.06
1983	8.03	2.22	0.20	0.16	0.05	16.86
1984	8.82	2.55	0.19	0.49	0.07	21.54
1985	9.04	2.47	0.29	0.14	0.05	14.25
1986	8.00	2.00	0.24	0.13	0.05	12.30
1987	9.00	1.00	0.10	0.11	0.02	7.70
1988	8.70	1.10	0.21	0.07	0.04	8.00
1989	8.70	0.77	0.15	0.05	0.03	6.20

continued

Table 30 (continued)

	Double Island, North Channel, Lake Huron					
Year	Perfat	DDE	Dieldrin	Mirex	HCB	PCB
1974	9.31	13.83	0.53	0.52	0.30	56.34
1975	7.25	16.22	0.41	0.55	0.24	46.01
1976	na	na	na	na	na	na
1977	9.42	19.03	0.51	0.55	0.21	76.90
1978	8.98	7.04	0.22	0.16	0.09	32.62
1979	8.72	2.06	0.32	0.17	0.10	26.24
1980	9.06	2.60	0.24	0.06	0.06	17.41
1981	9.58	3.56	0.23	0.17	0.07	23.08
1982	8.30	3.84	0.26	0.38	0.07	30.51
1983	8.45	3.25	0.25	0.15	0.05	19.69
1984	9.85	2.58	0.25	0.20	0.06	18.36
1985	9.51	3.08	0.32	0.29	0.07	19.56
1986	8.30	2.10	0.17	0.11	0.04	11.70
1987	8.60	1.60	0.33	0.06	0.02	9.00
1988	8.40	1.70	0.24	0.07	0.04	9.30
1989	8.80	2.40	0.25	0.14	0.04	14.00

	Port Colborne Lighthouse 1, Eastern Lake Erie					
Year	Perfat	DDE	Dieldrin	Mirex	HCB	PCB
1974	8.50	8.71	0.37	0.84	0.21	72.56
1975	8.21	7.92	0.38	0.42	0.16	53.91
1976	na	na	na	na	na	na
1977	9.84	7.55	0.50	0.51	0.19	59.27
1978	8.95	5.60	0.28	0.38	0.09	46.43
1979	8.59	3.44	0.24	0.25	0.10	37.59
1980	7.61	3.40	0.27	0.30	0.08	37.59
1981	9.63	4.74	0.24	0.42	0.08	44.36
1982	10.60	7.46	0.36	0.60	0.08	59.70
1983	8.27	3.05	0.17	0.29	0.06	36.76
1984	9.52	4.43	0.34	0.38	0.06	45.13
1985	9.17	3.62	0.16	0.24	0.05	29.66
1986	7.60	3.21	0.20	0.25	0.05	23.70
1987	9.60	1.70	0.14	0.21	0.03	16.00
1988	8.50	1.90	0.18	0.18	0.03	18.00
1989	10.40	3.10	0.23	0.33	0.05	33.00

continued

Table 30 (continued)

	Middle Island, Western Lake Erie					
Year	Perfat	DDE	Dieldrin	Mirex	HCB	PCB
1974	8.49	5.55	0.34	0.44	0.38	72.36
1975	8.44	6.90	0.28	0.22	0.23	70.69
1976	na	na	na	na	na	na
1977	9.00	7.42	0.31	0.39	0.19	78.13
1978	8.80	2.98	0.21	0.02	0.09	42.43
1979	8.12	2.76	0.27	0.10	0.12	59.28
1980	7.07	2.60	0.16	0.09	0.09	54.29
1981	8.64	3.06	0.20	0.07	0.10	68.61
1982	7.94	2.63	0.24	0.08	0.08	58.81
1983	7.77	1.66	0.24	0.04	0.05	37.92
1984	9.12	2.03	0.32	0.05	0.06	47.26
1985	9.04	2.04	0.22	0.05	0.07	47.15
1986	7.70	2.32	0.26	0.03	0.06	43.00
1987	8.70	1.70	0.14	0.01	0.04	28.00
1988	7.30	2.20	0.17	0.03	0.06	37.00
1989	8.80	2.20	0.11	0.03	0.05	76.00

	Snake Island, Eastern Lake Ontario					
Year	Perfat	DDE	Dieldrin	Mirex	HCB	PCB
1974	7.21	21.37	0.47	6.59	0.56	140.00
1975	7.81	23.58	0.35	5.97	0.22	179.59
1976	na	na	na	na	na	na
1977	9.64	16.96	0.50	2.91	0.50	120.00
1978	9.70	10.45	0.28	1.74	0.35	70.68
1979	8.55	8.83	0.19	1.96	0.22	62.90
1980	7.88	7.12	0.20	1.58	0.15	53.49
1981	9.51	11.75	0.27	2.80	0.26	85.62
1982	8.35	8.75	0.27	2.48	0.16	61.48
1983	8.06	5.07	0.21	1.50	0.09	46.18
1984	9.12	7.21	0.28	2.02	0.14	53.34
1985	9.19	7.15	0.18	1.68	0.08	34.59
1986	7.48	4.71	0.18	1.21	0.07	29.45
1987	8.90	2.90	0.15	0.86	0.05	17.00
1988	8.80	5.20	0.18	0.94	0.09	27.00
1989	8.60	5.20	0.14	1.10	0.07	31.00

continued

Table 30 (continued)

Year	Muggs Island, Western Lake Ontario					
	Perfat	DDE	Dieldrin	Mirex	HCB	PCB
1974	7.79	23.32	0.46	7.44	0.60	170.00
1975	7.69	22.02	0.24	3.42	0.45	110.00
1976	na	na	na	na	na	na
1977	8.79	12.80	0.28	2.05	0.34	86.62
1978	8.64	10.91	0.25	1.39	0.28	74.63
1979	8.73	9.05	0.22	1.81	0.21	76.29
1980	7.86	8.17	0.18	1.72	0.20	59.69
1981	8.93	10.26	0.28	2.53	0.23	72.17
1982	8.66	11.47	0.29	3.69	0.16	64.47
1983	8.49	4.49	0.14	1.36	0.07	39.01
1984	8.89	5.32	0.13	1.72	0.11	48.87
1985	9.14	4.90	0.13	1.26	0.06	36.57
1986	8.10	4.00	0.14	0.98	0.07	25.04
1987	9.00	2.30	0.11	0.50	0.03	16.00
1988	8.60	3.30	0.12	0.69	0.05	20.00
1989	7.90	5.30	0.30	1.20	0.06	34.00

Source: Environment Canada, Canadian Wildlife Service, Canada Centre for Inland Waters. 1990. Organochlorine contaminant concentrations in herring gull eggs from Great Lakes colonies. Burlington, ON.

Notes: Perfat=Percentage of fat in sample. DDE=Metabolite of dichloro-diphenyl-trichloro ethane (DDT). HCB=Hexachlorobenzene. PCB=Polychlorinated biphenyl. na=not available.

Table 31
Harvest-limited shellfish waters for selected estuaries, 1971-1985

(percentage of productive shellfish waters closed to harvest)

Year	Sheepscot Bay, MA	Merrimack River, MA	Connecticut River, CT	Narragansett Bay, RI	Saco Bay, NH
1971	48	100	100	29	19
1974	48	100	100	30	19
1980	44	100	100	32	20
1985	43	100	100	34	23

Year	Great South Bay, MA	Barnegat Bay, NJ	Delaware Bay, DE	Charleston Harbor, SC	Cape Fear River, NC
1971	12	17	14	100	NA
1974	12	19	15	100	88
1980	25	24	15	100	88
1985	24	24	15	100	67

Year	Santee River, GA	Broad River, SC	Mobile Bay, AL	Matagorda Bay, TX	Corpus Christi Bay, TX
1971	71	15	100	8	21
1974	71	15	100	11	21
1980	61	9	100	11	21
1985	59	12	100	12	24

Year	Galveston Bay, TX	Coos Bay, OR	Willapa Bay, WA	Puget Sound, WA	Grays Harbor, WA
1971	NA	87	3	35	24
1974	21	72	3	36	58
1980	51	73	3	35	24
1985	51	73	3	38	100

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Ocean Assessments Division, Strategic Assessment Branch. 1986. Trends in harvest-limited shellfish areas by estuary (data compiled from the National Estuarine Inventory database). Rockville, MD.

Table 32
Wetland acreage in the conterminous United States, 1780s-1980s

(millions of acres)

Wetland type	1780s	1954	1974	1980s
Estuarine wetlands	na	5.59	5.22	na
Freshwater marshes	na	33.07	28.40	na
Freshwater shrub wetlands	na	11.00	10.60	na
Freshwater forested wetlands	na	55.09	49.70	na
Other freshwater wetlands	na	2.70	5.00	na
Total wetland acreage	225.00	107.95	98.92	105.50

Source: Frayer, W.E., T.J. Monahan, D.C. Bowden & F.A. Graybill. 1983. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950s to 1970s, table 1, pp. 20, 21. Department of Forest and Wood Sciences, Colorado State University. Ft. Collins, CO.

U.S. Department of the Interior, Fish and Wildlife Service, National Wetlands Inventory. 1990. Wetland losses in the United States 1780's to 1980's (draft). Washington, D.C.

Table 33
Wetland acreage, by state, 1780s-1980s

State	Wetland area (million acres) 1780s	1980s	Percentage of wetland area lost
Alabama	7.567	3.783	50%
Alaska	170.200	170.000	<1%
Arizona	0.931	0.600	36%
Arkansas	9.848	2.763	72%
California	3.995	0.980	75%
Colorado	2.294	1.000	56%
Connecticut	0.670	0.173	74%
Delaware	0.480	0.022	54%
Florida	20.325	11.038	46%
Georgia	6.843	5.298	23%
Hawaii	0.150	0.100	33%
Idaho	0.877	0.385	56%
Illinois	8.212	1.254	85%
Indiana	5.600	0.750	87%
Iowa	4.500	0.800	80%

continued

Table 33 (continued)

State	Wetland area (million acres) 1780s	1980s	Percentage of wetland area lost
Kansas	0.841	0.453	48%
Kentucky	1.566	0.300	81%
Louisiana	16.194	8.784	46%
Maine	6.460	5.199	20%
Maryland	1.650	0.440	73%
Massachusetts	0.818	0.589	28%
Michigan	11.200	5.583	50%
Minnesota	15.070	8.700	42%
Mississippi	9.872	4.067	59%
Missouri	5.075	0.836	84%
Montana	1.147	0.840	27%
Nebraska	2.911	1.906	36%
Nevada	0.487	0.236	52%
New Hampshire	0.220	0.143	35%
New Jersey	1.500	0.915	39%
New Mexico	0.720	0.481	33%
New York	2.562	1.025	60%
North Carolina	11.089	5.689	49%
North Dakota	4.928	2.490	49%
Ohio	9.773	0.483	95%
Oklahoma	2.821	1.050	63%
Oregon	2.262	1.393	38%
Pennsylvania	1.127	0.499	56%
Rhode Island	0.102	0.065	37%
South Carolina	6.414	4.659	27%
South Dakota	2.735	1.780	35%
Tennessee	1.937	0.787	59%
Texas	15.999	7.612	52%
Utah	0.802	0.558	30%
Vermont	0.341	0.220	35%
Virginia	1.849	1.074	42%
Washington	1.350	0.938	31%
West Virginia	0.134	0.102	24%
Wisconsin	9.800	5.331	46%
Wyoming	2.000	1.250	38%

Source: U.S. Department of the Interior, Fish and Wildlife Service, National Wetlands Inventory.1990. Wetland losses in the United States 1780's to 1980's (draft). Washington, D.C.

Table 34
Loss of bottomland hardwood forests in the Mississippi River alluvial plain, 1937-1990

(million acres)

Year	Acreage	Year	Acreage	Year	Acreage
1937	12.35	1967	8.89	1985	4.55p
1947	11.36	1974	7.66	1990	4.20p
1957	10.62	1978	5.18		

Source: MacDonald, P.O., W.E. Frayer & J.K. Clauser. 1979. Documentation, chronology, and future projections of bottomland hardwood loss in the Lower Mississippi alluvial plain, vol. 1. U.S. Department of the Interior, Fish and Wildlife Service. Washington, D.C.

Note: p=projected.

Table 35
Oil and hazardous waste spills in and around U.S. waters, 1970-1986

	Oil spills		Hazardous waste spills	
Year	(thousands of spills)	(millions of gallons)	(number of spills)	(millions of pounds)
1970	3.71	15.25	na	na
1971	8.74	8.84	na	na
1972	9.93	18.81	na	na
1973	13.23	22.11	na	na
1974	14.43	19.42	42	1.12
1975	12.78	22.24	42	3.08
1976	13.93	36.61	54	13.16
1977	15.33	11.25	57	0.85
1978	14.50	17.56	49	0.24
1979	13.13	13.66	47	1.74
1980	11.16	15.09	63	0.27
1981	10.56	19.77	102	0.55
1982	10.41	23.15	175	8.66
1983	11.35	30.08	1,031	3.41
1984	13.02	18.16	1,433	3.80
1985	10.99	23.97	na	na
1986	9.21	5.53	na	na

Source: U.S. Department of Transportation, United States Coast Guard. Polluting incidents in and around U.S. waters, annual. COMDTINST M16450 series. Washington, D.C.

Note: na=not available.

Table 36
Annual global surface temperature anomalies, 1900-1988

(degrees Celsius)

Year	Variation	Year	Variation	Year	Variation
1900	0.01	1930	-0.03	1960	0.00
1901	-0.08	1931	0.05	1961	0.11
1902	-0.17	1932	-0.01	1962	0.10
1903	-0.30	1933	-0.11	1963	0.11
1904	-0.39	1934	-0.02	1964	-0.15
1905	-0.25	1935	-0.06	1965	-0.12
1906	-0.15	1936	-0.02	1966	-0.02
1907	-0.35	1937	0.1	1967	-0.04
1908	-0.34	1938	0.14	1968	-0.08
1909	-0.25	1939	0.04	1969	0.08
1910	-0.25	1940	0.04	1970	0.05
1911	-0.30	1941	0.07	1971	-0.10
1912	-0.21	1942	0.01	1972	0.02
1913	-0.21	1943	0.00	1973	0.15
1914	-0.09	1944	0.15	1974	-0.11
1915	0.00	1945	0.06	1975	-0.02
1916	-0.21	1946	-0.08	1976	-0.21
1917	-0.40	1947	-0.05	1977	0.10
1918	-0.29	1948	-0.06	1978	0.03
1919	-0.16	1949	-0.06	1979	0.12
1920	-0.17	1950	-0.13	1980	0.18
1921	-0.12	1951	-0.02	1981	0.24
1922	-0.20	1952	0.07	1982	0.09
1923	-0.18	1953	0.11	1983	0.31
1924	-0.19	1954	-0.13	1984	0.10
1925	-0.12	1955	-0.14	1985	0.07
1926	0.07	1956	-0.23	1986	0.16
1927	-0.04	1957	0.07	1987	0.33
1928	-0.05	1958	0.12	1988	0.34
1929	-0.22	1959	0.05		

Source: Jones, P.D. Climatic Research Unit, University of East Angola, Norwich, United Kingdom. (Data provided by the Carbon Dioxide Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN).

Note: Global surface temperature anomalies are relative to a 1957-1979 reference period mean. El Nino/Southern Oscillation effects have not been removed. Some climatologists would say that the build-up of greenhouse gases in the atmosphere is the most likely cause of the long-term warming trend, whereas other climatologists would say that the recent warming trend is simply a manifestation of El Nino/Southern Oscillation events in the Pacific.

Table 37
Global emissions of carbon dioxide from anthropogenic sources, 1950-1987

(million metric tons of carbon)

Year	Emissions	Year	Emissions
1950	1,638	1969	3,809
1951	1,775	1970	4,090
1952	1,803	1971	4,241
1953	1,848	1972	4,409
1954	1,871	1973	4,647
1955	2,050	1974	4,655
1956	2,185	1975	4,628
1957	2,278	1976	4,894
1958	2,338	1977	5,033
1959	2,471	1978	5,082
1960	2,586	1979	5,365
1961	2,602	1980	5,263
1962	2,708	1981	5,129
1963	2,855	1982	5,097
1964	3,016	1983	5,088
1965	3,154	1984	5,263
1966	3,314	1985	5,382
1967	3,420	1986	5,565
1968	3,595	1987	5,650

Source: Marland, G. Oak Ridge National Laboratory. (Data provided by the Carbon Dioxide Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN).

Note: Emissions from anthropogenic sources include emissions from fossil fuel consumption, cement manufacturing, and gas flaring.

Table 38
Average annual concentration of carbon dioxide in the atmosphere, 1958-1988

(parts per million by volume basis)

Year	Mauna Loa, Hawaii	South Pole	American Samoa	Point Barrow, Alaska
1958	na	314.5	na	na
1959	316.1	315.5	na	na
1960	317.0	316.9	na	na
1961	317.7	317.7	na	na
1962	318.6	318.1	na	na
1963	319.1	318.1	na	na
1964	319.6	318.3	na	na
1965	320.4	319.3	na	na
1966	321.1	320.6	na	na
1967	322.0	321.3	na	na
1968	322.8	321.6	na	na
1969	324.2	322.4	na	na
1970	325.5	324.1	na	na
1971	326.5	324.8	na	na
1972	327.6	325.9	na	na
1973	329.8	327.4	na	327.9
1974	330.4	328.3	na	332.6
1975	331.0	329.3	na	333.3
1976	332.1	330.4	330.6	333.7
1977	333.6	331.8	332.5	334.7
1978	335.2	333.6	335.3	336.7
1979	336.5	334.8	336.3	337.9
1980	338.4	336.9	338.0	339.9
1981	339.5	338.1	338.3	341.7
1982	340.8	339.3	340.3	342.8
1983	342.8	341.0	341.6	344.1
1984	344.3	342.4	343.3	346.0
1985	345.7	343.7	344.4	347.0
1986	346.9	345.2	345.9	348.7
1987	348.6	346.8	347.6	349.8
1988	351.2	348.5	349.7	352.9

Source: Keeling, C.D. Scripps Institution of Oceanography, La Jolla, CA. (Data provided by the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN).

Thoning, K.W. Cooperative Institute for Research in Environmental Studies, University of Colorado, Boulder, CO. (Data provided by the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN).

Note: na=not available.

Table 39
Global annual releases of chlorofluorocarbons, 1931-1988

(million kilograms)

Year	CFC-11	CFC-12	Year	CFC-11	CFC-12
1931	0.0	0.1	1960	40.5	89.1
1932	0.0	0.1	1961	52.1	99.7
1933	0.0	0.1	1962	65.4	114.5
1934	0.0	0.2	1963	80.0	133.9
1935	0.0	0.3	1964	95.0	155.5
1936	0.0	0.5	1965	108.3	175.4
1937	0.0	0.8	1966	121.3	195.0
1938	0.1	1.2	1967	137.6	219.9
1939	0.1	1.7	1968	156.8	246.5
1940	0.1	2.3	1969	181.9	274.3
1941	0.1	3.0	1970	206.6	299.9
1942	0.1	3.7	1971	226.9	321.8
1943	0.2	4.5	1972	255.8	349.9
1944	0.2	6.1	1973	292.4	387.3
1945	0.3	8.0	1974	321.4	418.6
1946	0.6	13.9	1975	310.9	404.1
1947	1.3	21.3	1976	316.7	390.4
1948	2.3	24.8	1977	303.9	371.2
1949	3.8	26.6	1978	283.6	341.3
1950	5.5	29.5	1979	263.7	337.5
1951	7.6	32.4	1980	250.8	332.5
1952	11.0	33.7	1981	248.2	340.7
1953	15.0	37.9	1982	239.5	337.4
1954	18.6	42.9	1983	252.8	343.3
1955	23.0	48.2	1984	271.1	359.4
1956	28.7	56.1	1985	280.8	368.4
1957	32.2	63.8	1986	295.1	376.5
1958	30.2	66.9	1987	310.6	386.5
1959	30.9	74.8	1988	314.5	392.8

Source: Chemical Manufacturers Association. 1989. Production, sales, and calculated release of CFC-11 and CFC-12 through 1988, table 3. Washington, D.C.

Note: Data are supplied by reporting companies participating in the Chemical Manufacturers Association's chlorofluorocarbon research program.

Table 40
Global concentrations of atmospheric trace gases, 1975-1985

Year	CFC-11 (ppt)	CFC-12 (ppt)	Nitrogen dioxide (ppb)	Methane (ppb)
1975	120	200	291.4	1,525
1976	133	217	293.3	1,555
1977	148	239	294.6	1,573
1978	159	266	296.4	1,596
1979	167	283	296.3	1,619
1980	179	307	297.6	1,639
1981	185	315	298.5	1,656
1982	193	330	301.0	1,671
1983	205	350	300.9	1,663
1984	213	366	300.4	1,689
1985	223	384	301.5	1,711

Source: Rasmussen, R.A. & M.A.K. Khalil. 1986. Atmospheric trace gases: trends and distributions over the last decade. Science, 232: 1623-1624.

Notes: ppt=parts per trillion. ppb=parts per billion.

Table 41
National ambient concentrations of criteria air pollutants, 1975-1987

Year	Sulfur dioxide (ppm)	Carbon monoxide (ppm)	Ozone (ppm)	Nitrogen dioxide (ppm)	TSP (ug/m3)	Lead (mg/m3)
1975	0.0154	11.96	0.153	0.029	61.9	1.04
1976	0.0156	11.32	0.153	0.029	62.8	1.05
1977	0.0138	10.66	0.155	0.029	62.9	1.16
1978	0.0129	10.17	0.156	0.029	62.4	1.04
1979	0.0122	9.80	0.142	0.029	63.4	0.79
1980	0.0108	9.08	0.145	0.028	64.8	0.55
1981	0.0104	8.82	0.131	0.027	60.2	0.44
1982	0.0980	8.13	0.128	0.026	50.2	0.47
1983	0.0094	8.02	0.145	0.025	49.7	0.39
1984	0.0095	8.00	0.130	0.026	50.9	0.35
1985	0.0089	7.19	0.127	0.025	48.5	0.23
1986	0.0086	7.21	0.123	0.025	48.4	0.15
1987	0.0084	6.88	0.129	0.025	49.4	0.12

Source: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. 1989. National air quality and emissions trends report, 1987. EPA-450/4-09-001. Research Triangle Park, NC.

Notes: ppm=parts per million. ug/m3=micrograms per cubic meter. mg/m3=milligrams per cubic meter. TSP=total suspended particulates. Sulfur dioxide and nitrogen dioxide records are arthmetic means. Carbon monoxide and ozone records are second maximum readings over 8- and 24- hour periods, respectively. TSP records are geometric means. Lead records are maximum quarterly recordings.

Table 42
U.S. emissions of criteria air pollutants, by source, 1940-1987

(million metric tons)

	Sulfur dioxide					
Year	Transportation	Fuel combustion	Industrial processes	Solid waste	Miscellaneous	Total
1940	2.9	11.0	3.7	0.0	0.5	17.6
1950	2.3	12.9	4.6	0.0	0.5	19.8
1960	0.4	14.0	5.3	0.0	0.5	19.7
1970	0.6	21.3	6.4	0.0	0.1	28.3
1975	0.6	20.3	4.7	0.0	0.0	25.6
1976	0.7	20.9	4.6	0.0	0.0	26.2
1977	0.8	21.5	4.7	0.0	0.0	26.9
1978	0.8	19.9	4.3	0.0	0.0	25.0
1979	0.9	19.8	4.4	0.0	0.0	25.1
1980	0.9	19.3	3.8	0.0	0.0	23.9
1981	0.9	18.8	3.9	0.0	0.0	23.5
1982	0.8	17.8	3.3	0.0	0.0	22.0
1983	0.8	17.4	3.3	0.0	0.0	21.5
1984	0.8	17.9	3.3	0.0	0.0	22.1
1985	0.9	17.6	3.2	0.0	0.0	21.6
1986	0.9	17.2	3.1	0.0	0.0	21.2
1987	0.9	16.4	3.1	0.0	0.0	20.4

	Nitrogen oxides					
Year	Transportation	Fuel combustion	Industrial processes	Solid waste	Miscellaneous	Total
1940	2.2	3.4	0.2	0.1	0.9	6.8
1950	3.5	4.7	0.3	0.2	0.6	9.3
1960	4.9	6.7	0.5	0.3	0.4	12.8
1970	7.6	9.1	0.7	0.4	0.3	18.1
1975	8.9	9.4	0.7	0.1	0.1	19.2
1976	9.3	10.0	0.7	0.1	0.2	20.3
1977	9.5	10.4	0.7	0.1	0.2	21.0
1978	9.7	10.3	0.7	0.1	0.2	21.1
1979	9.5	10.5	0.7	0.1	0.2	21.0
1980	9.2	10.1	0.7	0.1	0.2	20.3
1981	9.3	10.0	0.6	0.1	0.2	20.3
1982	8.9	9.9	0.5	0.1	0.1	19.5
1983	8.6	9.6	0.5	0.1	0.2	19.1
1984	8.7	10.2	0.6	0.1	0.2	19.7
1985	8.8	10.2	0.6	0.1	0.1	19.7
1986	8.5	10.0	0.6	0.1	0.1	19.3
1987	8.4	10.3	0.6	0.1	0.1	19.5

continued

Table 42 (continued)

Year	Volatile organic compounds					
	Transportation	Fuel combustion	Industrial processes	Solid waste	Miscellaneous	Total
1940	5.2	4.7	3.3	0.9	4.6	18.6
1950	7.9	3.1	5.4	1.0	3.6	21.0
1960	11.1	1.9	6.3	1.4	3.1	23.8
1970	12.4	1.1	8.9	1.8	3.3	27.5
1975	10.3	1.0	8.1	0.9	2.5	22.8
1976	10.4	1.2	8.7	0.8	2.9	24.0
1977	10.0	1.4	9.3	0.8	2.8	24.1
1978	9.7	1.6	9.9	0.8	2.7	24.7
1979	8.9	1.9	9.8	0.7	2.9	24.3
1980	8.2	2.2	9.2	0.6	2.9	23.0
1981	7.9	2.3	8.3	0.6	2.5	21.6
1982	7.4	2.5	7.4	0.6	2.2	20.1
1983	7.3	2.6	7.8	0.6	2.7	20.9
1984	7.3	2.6	8.7	0.6	2.7	21.9
1985	6.7	2.3	8.4	0.6	2.2	20.3
1986	6.5	2.3	7.9	0.6	2.2	19.5
1987	6.0	2.3	8.3	0.6	2.4	19.6

Year	Total suspended particulates					
	Transportation	Fuel combustion	Industrial processes	Solid waste	Miscellaneous	Total
1940	2.7	7.5	8.7	0.5	3.7	23.1
1950	2.1	7.0	12.7	0.6	2.5	24.9
1960	0.7	5.7	12.5	0.9	1.8	21.6
1970	1.2	4.6	10.5	1.1	1.1	18.5
1975	1.4	2.7	5.0	0.6	0.7	10.4
1976	1.4	2.5	4.4	0.4	1.0	9.7
1977	1.4	2.5	4.0	0.4	0.8	9.1
1978	1.4	2.5	4.0	0.4	0.8	9.1
1979	1.4	2.5	3.8	0.4	0.9	8.9
1980	1.3	2.4	3.3	0.4	1.1	8.5
1981	1.3	2.3	2.6	0.4	0.9	8.0
1982	1.3	2.2	2.4	0.3	0.7	7.1
1983	1.3	2.0	2.4	0.3	1.1	7.1
1984	1.3	2.1	2.8	0.3	0.9	7.4
1985	1.4	1.8	2.8	0.3	0.8	7.0
1986	1.4	1.8	2.5	0.3	0.8	6.8
1987	1.4	1.8	2.5	0.3	1.0	7.0

continued

Table 42 (continued)

Year	Carbon monoxide					
	Transportation	Fuel combustion	Industrial processes	Solid waste	Miscellaneous	Total
1940	29.3	15.9	6.6	3.3	26.5	81.6
1950	43.6	11.4	10.5	4.3	16.5	86.3
1960	57.0	7.0	9.3	5.1	10.0	88.3
1970	71.8	4.4	8.9	6.4	7.2	98.7
1975	62.0	4.4	6.9	3.1	4.8	81.2
1976	64.3	4.7	7.1	2.7	7.1	85.9
1977	61.0	5.1	7.3	2.6	5.8	81.8
1978	61.6	5.8	7.2	2.5	5.7	82.4
1979	56.9	6.6	7.1	2.3	6.5	79.4
1980	53.5	7.3	6.3	2.2	7.6	77.0
1981	52.5	7.5	5.9	2.1	6.4	74.4
1982	50.0	8.0	4.4	2.0	4.9	69.4
1983	49.3	7.9	4.4	1.9	7.7	71.3
1984	47.6	8.1	4.8	1.9	6.3	68.7
1985	45.5	7.2	4.6	2.0	5.3	64.6
1986	42.8	7.2	4.5	1.7	5.0	61.1
1987	40.7	7.2	4.7	1.7	7.1	61.4

Source: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. 1989. National air quality and emissions trends report, 1987. EPA-450/4-09-001. Research Triangle Park, NC.

Table 43
U.S. emissions of lead, by source, 1970-1987

(thousand metric tons)

Year	Transportation	Fuel combustion	Industrial processes	Solid waste	Total
1970	163.6	9.6	23.9	6.7	203.8
1975	122.6	9.3	10.3	4.8	147.0
1976	132.4	8.3	8.1	4.3	153.1
1977	124.2	7.2	5.7	4.1	141.2
1978	112.4	6.1	5.4	4.0	127.9
1979	94.6	4.9	5.2	4.0	108.7
1980	59.4	3.9	3.6	3.7	70.6
1981	46.4	2.8	3.0	3.7	55.9
1982	46.9	1.7	2.7	3.1	54.4
1983	40.7	0.6	2.4	2.6	46.3
1984	34.7	0.5	2.3	2.6	40.1
1985	15.5	0.5	2.3	2.8	21.1
1986	3.5	0.5	1.9	2.7	8.6
1987	3.0	0.5	2.0	2.6	8.1

Source: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. 1989. National air quality and emissions trends report, 1987. EPA-450/4-09-001. Research Triangle Park, NC.

Table 44
Ownership of land in the United States, 1955-1987

Year	Federal (million acres)	Federal (percent)	Nonfederal (million acres)	Nonfederal (percent)	Total (million acres)
1955	408	21.4	1,496	78.6	1,904
1960	772	33.9	1,502	66.1	2,273
1965	766	33.5	1,506	66.5	2,271
1970	761	33.5	1,510	66.5	2,271
1975	760	33.5	1,511	66.5	2,271
1980	720	31.7	1,552	68.3	2,271
1985	727	32.0	1,545	68.0	2,271
1987	724	31.9	1,547	68.1	2,271

Source: U.S. Department of Commerce, Bureau of the Census. Statistical abstract of the United States, annual. Washington, D.C.

Table 45
Major uses of land, 1900-1987

(million acres)

Year	Cropland	Grazing land	Forest land	Special use	Other land	Total
1900	319	832	719	na	400	1,904
1910	347	814	562	na	424	1,904
1920	402	750	567	86	330	1,904
1930	413	708	607	na	416	1,904
1940	399	723	602	99	327	1,904
1959	359	633	728	146	306	2,271
1969	333	604	723	306	293	2,264
1974	361	598	718	182	301	2,264
1978	369	587	703	158	345	2,264
1982	383	597	655	270	274	2,265
1987	464	588	652	279	282	2,265

Source: U.S. Department of Agriculture, Economic Research Service. Major uses of land in the United States. AER 535 and earlier issues in this series. Washington, D.C.

Notes: The total land area of the United States increased in 1959 with the addition of Alaska and Hawaii as states. Other changes in total land area result from refinements in measuring techniques. Within category changes result from gains and losses from bases. The estimates for different years are not strictly comparable.

Table 46
Special uses of land, 1949-1987

(million acres)

Land use	1949	1959	1969	1974	1978	1982	1987
Urban	18	24	31	35	na	na	na
Transportation	24	25	26	26	27	27	26
Recreation	40	44	49	52	57	116	128
Wildlife	17	17	32	36	41	95	96
National defense & industrial	26	26	26	25	25	24	21
Farmsteads & farm roads	10	10	8	8	8	8	6
Total	136	146	172	182	158	270	279

Source: U.S. Department of Agriculture, Economic Research Service. Major uses of land in the United States. AER 535 and earlier issues in this series. Washington, D.C.

Table 47
Number of farms and land in farms, 1860-1987

Year	Number (million)	Land (billion acres)	Year	Number (million)	Land (billion acres)
1860	2.000	na	1945	5.859	1.142
1880	4.000	na	1950	5.388	1.161
1890	4.565	na	1954	4.783	1.160
1900	5.740	0.839	1959	3.708	1.123
1910	6.366	0.879	1964	3.158	1.110
1920	6.454	0.956	1969	2.730	1.063
1925	6.372	na	1974	2.314	1.017
1930	6.295	0.990	1978	2.258	1.015
1935	6.812	na	1982	2.241	0.987
1940	6.102	1.065	1987	2.088	0.964

Source: U.S. Department of Commerce, Bureau of the Census. 1976. Historical statistics of the United States: Colonial times to 1970. Washington, D.C.

U.S. Department of Commerce, Bureau of the Census. Census of agriculture for 1987 and earlier years. Washington, D.C.

Note: na=not available.

Table 48
Number of farms and land in farms, by farm size, 1900-1987

	Farm size							
	1-49 acres		50-499 acres		500-999 acres		1,000+ acres	
Year	Number (millions)	Land (million acres)	Number (millions)	Land (million acres)	Number (millions)	Land (million acres)	Number (millions)	Land (million acres)
1900	1.93	49	3.37	520	0.10	68	0.05	200
1910	2.25	49	3.93	570	0.13	84	0.05	167
1920	2.31	59	3.93	580	0.15	100	0.07	221
1925	2.42	57	3.75	550	0.14	97	0.06	224
1930	2.36	56	3.69	550	0.16	109	0.08	277
1935	2.69	59	3.86	540	0.17	114	0.09	310
1940	2.29	50	3.55	540	0.16	112	0.10	366
1945	2.25	47	3.32	520	0.17	119	0.11	460
1950	1.97	39	3.12	500	0.18	126	0.12	495
1954	1.70	32	2.76	460	0.19	132	0.13	531
1959	1.06	22	2.32	410	0.20	137	0.14	555
1964	0.82	17	1.98	360	0.21	145	0.15	585
1969	0.64	14	1.73	320	0.22	148	0.15	578
1974	0.51	11	1.44	273	0.21	142	0.16	590
1978	0.54	12	1.34	256	0.21	147	0.16	600
1982	0.64	13	1.24	233	0.20	141	0.16	600
1987	0.59	12	0.87	212	0.20	139	0.17	602

Source: U.S. Department of Commerce, Bureau of the Census. 1976. Historical statistics of the United States: Colonial times to 1970. Washington, D.C.

U.S. Department of Commerce, Bureau of the Census. Census of agriculture for 1987 and earlier years. Washington, D.C.

Table 49
Prime farmland, by land cover type, 1977-1987

(million acres)

Use	1977	1982	1987
Cropland	230	233	232
Pastureland	40	39	37
Rangeland	22	20	19
Forest land	42	45	45
Minor land	11	7	7
Total	345	340	339

Source: U.S. Department of Agriculture, Soil Conservation Service & Iowa State University Statistical Laboratory. Natural resources inventory: 1977, 1982, and 1987. Washington, D.C.

Table 50
Major uses of cropland, 1945-1989

(million acres)

Year	Cropland used for crops: Harvested	Failed	Summer fallow	Idle	Cropland pasture	Total	Diverted from production
1945	353	10	40	na	47	454	na
1949	352	9	26	22	67	478	na
1954	339	13	28	19	66	465	na
1959	317	10	31	33	66	457	22.5
1964	292	6	37	52	57	444	55.0
1969	286	6	41	51	88	472	57.5
1974	322	8	31	21	83	465	2.7
1978	330	7	32	26	76	471	18.3
1982	347	5	31	21	65	469	11.1
1986	316	8	32	na	na	na	48.1
1987	293	6	32	68	65	465	76.2
1988	287	10	30	na	na	na	77.6
1989	306	8	27	na	na	na	59.5

Source: U.S. Department of Agriculture, Economic Research Service. Cropland, water and conservation situation and outlook report, annual. Washington, D.C.

Notes: Acres of idle cropland, cropland pasture, and total cropland are estimated only for years coinciding with Census of Agriculture years. Data are for the 48 conterminous United States. Cropland diversions occurred under federal farm programs. Data for 1989 are preliminary.

Table 51
Cropland erosion, 1977-1987

(average annual tons per acre)

Year	Sheet and rill erosion: Cultivated cropland	Uncultivated cropland	Average	Wind erosion: Cultivated cropland	Uncultivated cropland	Average
1977	5.1	3.4	4.7	6.0	1.9	5.3
1982	4.7	0.8	4.3	3.4	0.4	3.1
1987	4.1	0.9	3.8	3.6	0.7	3.3

Source: U.S. Department of Agriculture, Soil Conservation Service. National resources inventory: 1977, 1982, and 1987. Washington, D.C.

Notes: Data for 1977 are not strictly comparable with data for 1982 and 1987 because of different reporting categories.

Table 52
Agricultural productivity indexes, 1969-1988

Index (1977=100)

Year	Inputs				Output	Productivity
	Labor	Mechanical	Chemical	Total		
1969	118	86	73	97	85	88
1970	112	85	75	97	84	87
1971	108	87	81	98	92	94
1972	110	86	86	97	91	94
1973	109	90	90	98	93	95
1974	109	92	92	98	88	90
1975	106	96	83	96	95	99
1976	100	98	96	99	97	98
1977	100	100	100	100	100	100
1978	100	104	107	102	104	102
1979	99	104	123	105	111	109
1980	96	101	123	103	104	101
1981	96	98	129	102	118	116
1982	93	94	118	99	116	118
1983	97	89	105	97	96	99
1984	92	88	121	95	112	118
1985	85	83	123	92	118	128
1986	80	75	110	87	111	127
1987	78	72	111	86	110	128
1988	75	71	113	85	102	120

Source: U.S. Department of Agriculture, Economic Research Service. Economic indicators of the farm sector: Production and efficiency statistics, annual. Washington, D.C.

Table 53
Farm fuel use, 1974-1989

(billions of gallons)

Year	Gasoline	Diesel	LP gas
1974	3.7	2.6	1.4
1975	4.5	2.4	1.0
1976	3.9	2.8	1.2
1977	3.8	2.9	1.1
1978	3.6	3.2	1.3
1979	3.4	3.2	1.1
1980	3.0	3.2	1.1
1981	2.7	3.1	1.0
1982	2.4	2.9	1.1
1983	2.3	3.0	0.9
1984	2.1	3.0	0.9
1985	1.9	2.9	0.9
1986	1.7	2.9	0.7
1987	1.5	3.0	0.6
1988	1.6	2.8	0.6
1989	1.6	3.2	0.6

Source: U.S. Department of Agriculture, Economic Research Service. Agricultural resources: Inputs outlook and situation report, periodic. Washington, D.C.

Note: Data for 1989 are preliminary.

Table 54
Farm fertilizer use, 1939-1989

(millions of tons of primary nutrients - nitrogen, phosphorus, and potash)

Year	Amount	Year	Amount	Year	Amount
1939	1.6	1956	6.1	1973	18.0
1940	1.8	1957	6.4	1974	19.3
1941	1.9	1958	6.5	1975	17.6
1942	2.1	1959	7.4	1976	20.8
1943	2.4	1960	7.5	1977	22.1
1944	2.6	1961	7.8	1978	20.6
1945	2.7	1962	8.4	1979	22.6
1946	3.1	1963	9.5	1980	23.1
1947	3.3	1964	10.5	1981	23.7
1948	3.6	1965	11.0	1982	21.4
1949	3.9	1966	12.4	1983	18.1
1950	4.1	1967	14.0	1984	21.8
1951	4.7	1968	15.0	1985	21.7
1952	5.2	1969	15.5	1986	19.7
1953	5.6	1970	16.1	1987	19.1
1954	5.9	1971	17.2	1988	19.6
1955	6.1	1972	17.2	1989	19.6

Source: U.S. Department of Agriculture, Economic Research Service. Agricultural resources: Inputs outlook and situation report, periodic. Washington, D.C.

Table 55
Farm pesticide use, 1964-1989

(million pounds of active ingredients)

Year	Herbicides	Insecticides	Other	Total
1964	76	143	72	291
1966	112	138	78	328
1971	207	127	130	464
1976	374	130	146	650
1982	451	71	30	552
1986	410	59	6	475
1987	365	57	7	429
1988	372	60	8	440
1989	394	61	8	463

Source: U.S. Department of Agriculture, Economic Research Service. Inputs outlook and situation report, periodic. Washington, D.C.

Notes: For the years 1964, 1966, 1972, and 1976, estimates of pesticide use are for total use on all crops and livestock in the United States. The 1982 estimates are for major field and forage crops only and represent 33 major producing states, excluding California. The 1986-1989 estimates are for 10 major field crops.

Table 56
Irrigated farmland, 1900-1987

(million acres)

Year	Leading irrigation states	All other states	Total
1900	7.5	0.3	7.8
1910	11.3	0.4	11.7
1920	13.9	0.6	14.5
1930	14.1	0.6	14.7
1940	17.2	0.7	18.0
1950	24.3	1.5	25.8
1959	30.7	2.4	33.2
1964	33.2	3.8	37.1
1969	34.8	4.3	39.1
1974	37.0	4.0	41.0
1978	47.8	2.6	50.4
1982	46.1	2.9	49.0
1984	42.1	2.6	44.7
1987	45.9	6.0	51.9

Source: U.S. Department of Commerce, Bureau of the Census. Census of agriculture and other special ranch and irrigation surveys. Washington, D.C.

Notes: Leading irrigation states for 1900-1974 are the 17 Western states: Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. Leading states for 1978 and 1982 are the 17 Western States plus Florida, Georgia, and Louisiana. Leading states for 1984 and 1987 are the 17 Western states plus Arkansas, Georgia, and Louisiana. All other states are conterminous states.

Table 57
Rangeland condition, 1936-1988

(percentage of total acreage)

	Nonfederal rangeland				BLM rangeland			
Condition	1963	1977	1982	1987	1936	1966	1975	1988
Excellent	5	12	4	3	2	2	2	4
Good	15	28	30	30	14	17	15	30
Fair	40	42	45	47	48	52	50	38
Poor	40	18	16	14	36	30	33	17
Other	na	na	5	6	na	na	na	11

Source: U.S. Department of Agriculture, Soil Conservation Service. National resources inventory: 1977, 1982, and 1987; and earlier surveys. Washington, D.C.

U.S. Department of the Interior, Bureau of Land Management. Public land statistics, annual. Washington, D.C.

Notes: BLM=Bureau of Land Management. na=not available. Data are not strictly comparable because of different survey methods.

Table 58
Forest conditions, 1930-1989

(million acres)

Year	Wildfire damage	Reforestation	Year	Wildfire damage	Reforestation
1930	52.3	0.14	1969	6.7	1.43
1940	25.9	0.52	1970	3.3	1.60
1950	15.5	0.50	1971	4.3	1.69
1951	10.8	0.45	1972	2.6	1.68
1952	14.2	0.52	1973	1.9	1.75
1953	10.0	0.71	1974	2.9	1.60
1954	8.8	0.81	1975	1.8	1.93
1955	8.1	0.78	1976	5.1	1.89
1956	6.6	0.89	1977	3.2	1.98
1957	3.4	1.14	1978	3.9	2.09
1958	3.3	1.53	1979	3.0	2.06
1959	4.2	2.12	1980	5.3	2.27
1960	4.5	2.14	1981	4.8	1.93
1961	3.0	1.76	1982	2.4	2.37
1962	4.1	1.37	1983	5.1	2.45
1963	7.1	1.33	1984	3.0	2.55
1964	4.2	1.31	1985	5.2	2.70
1965	2.7	1.29	1986	3.2	2.75
1966	4.6	1.28	1987	5.0	3.03
1967	4.7	1.37	1988	5.7	3.39
1968	4.2	1.44	1989	1.5p	na

Source: U.S. Department of Agriculture, Forest Service. Wildfire statistics, annual. Washington, D.C.

U.S. Department of Agriculture, Forest Service. U.S. forest planting report, annual. Washington, D.C.

Notes: Reforestation refers to acres planted in seedlings and directed seeded. p=preliminary estimates reported to the Boise Interagency Fire Center as of September 1989. na=not available.

Table 59
Forest land damaged by insects, 1968-1988

(million acres)

Year	Eastern spruce budworm	Western spruce budworm	Gypsy moth	Mountain pine beetle	Southern pine beetle
1968	1.3	5.3	0.1	na	na
1969	1.2	4.6	0.3	na	na
1970	2.0	4.0	1.0	na	na
1971	1.6	4.8	1.9	na	na
1972	2.8	5.5	1.4	na	na
1973	4.2	4.4	1.8	na	na
1974	10.8	5.5	0.8	na	na
1975	9.2	5.3	0.5	na	na
1976	9.1	5.8	0.9	na	na
1977	10.3	6.5	1.6	na	na
1978	7.7	5.2	1.3	4.0	na
1979	6.6	5.0	0.6	4.4	15.0
1980	6.6	4.0	5.0	4.7	12.1
1981	4.5	5.5	12.9	4.7	0.9
1982	4.2	8.7	8.2	4.2	7.3
1983	6.5	11.0	2.4	3.6	11.4
1984	6.1	10.6	1.0	3.3	na
1985	5.2	12.8	1.7	3.3	15.5
1986	1.0	13.2	2.4	3.5	26.4
1987	0.8	8.0	1.3	2.4	13.8
1988	0.3	6.1	0.7	2.2	7.9

Source: U.S. Department of Agriculture, Forest Service, Forest Pest Management. 1985. Insect and disease conditions in the United States 1979-1983. Washington, D.C.

U.S. Department of Agriculture, Forest Service, Forest Pest Management. Forest insect and disease conditions in the United States, annual (after 1984). Washington, D.C.

Note: na=not available.

Table 60
Roundwood harvest, by product, 1950-1990

(billion cubic feet)

Year	Lumber	Plywood & veneer	Pulp products	Fuel	Miscel-laneous	Total
1950	5.9	0.3	1.5	2.3	0.8	10.8
1951	5.8	0.4	1.8	2.2	0.7	11.0
1952	5.8	0.4	1.8	2.0	0.7	10.8
1953	5.7	0.5	1.9	1.9	0.7	10.7
1954	5.6	0.5	2.0	1.8	0.7	10.6
1955	5.8	0.6	2.2	1.7	0.7	11.0
1956	5.9	0.6	2.5	1.7	0.6	11.3
1957	5.1	0.6	2.4	1.6	0.6	10.2
1958	5.2	0.6	2.2	1.5	0.6	10.0
1959	5.7	0.7	2.4	1.4	0.6	10.8
1960	5.1	0.7	2.6	1.3	0.6	10.2
1961	4.9	0.8	2.5	1.2	0.6	10.0
1962	5.1	0.8	2.6	1.1	0.6	10.2
1963	5.4	0.9	2.7	1.1	0.7	10.6
1964	5.6	1.0	2.9	1.0	0.7	11.2
1965	5.7	1.0	3.1	0.9	0.8	11.5
1966	5.6	1.0	3.2	0.8	0.8	11.5
1967	5.3	1.0	3.2	0.8	0.9	11.2
1968	5.5	1.1	3.4	0.7	1.0	11.8
1969	5.4	1.1	3.6	0.6	1.0	11.6
1970	5.2	1.0	3.8	0.5	1.0	11.6
1971	5.4	1.2	3.6	0.5	0.9	11.5
1972	5.5	1.3	3.5	0.5	1.1	11.9
1973	5.7	1.3	3.8	0.5	1.2	12.4
1974	5.1	1.1	4.2	0.5	1.1	12.1
1975	4.9	1.2	3.5	0.6	1.0	11.1
1976	5.6	1.4	3.8	0.6	1.2	12.5
1977	5.9	1.4	3.6	1.0	1.2	13.2
1978	6.2	1.5	3.7	1.5	1.2	14.1
1979	6.1	1.4	4.1	2.2	1.4	15.2
1980	5.3	1.2	4.4	3.1	1.2	15.2
1981	4.6	1.2	4.1	3.2	0.9	14.1
1982	4.6	1.1	4.0	3.4	1.1	14.2
1983	5.4	1.4	4.2	3.2	1.1	15.2
1984	5.8	1.4	4.4	3.6	1.2	15.9
1985	5.7	1.4	4.2	3.4	1.2	15.8
1986	6.5	1.5	4.5	3.1	1.2	17.0
1987	7.0	1.6	4.7	3.0	1.4	17.7
1988	7.0	1.6	4.8	3.0	1.5	17.9
1989	6.6	1.6	5.0	3.0	1.5	17.7
1990	6.7	1.6	5.0	2.9	1.7	17.9

Source: U.S. Department of Agriculture, Forest Service. 1988. U.S. timber production, trade, consumption, and price statistics, 1950-1986, table 4, p. 13. Washington, D.C.

Notes: Miscellaneous includes log exports, pulp chip exports, and other roundwood products not specified. Data for 1987-1989 are preliminary. Data for 1990 are projections.

Table 61
National Park System, 1872-1989

Year	Number of units	Land (million acres)
1872	1	2.20
1880	5	2.20
1890	12	3.80
1900	17	4.10
1910	45	7.90
1920	62	9.90
1930	98	10.80
1940	161	22.30
1950	182	24.60
1960	187	26.20
1970	282	29.60
1980	333	77.00
1986	337	79.50
1987	343	79.60
1988	354	80.00
1989	365	80.10

Source: U.S. Department of the Interior, National Park Service. Areas administered by the National Park Service: Information Tables, annual. Washington, D.C.

Table 62
National Wildlife Refuges, 1920-1989

Year	Number of units	Land (million acres)
1920	36	na
1940	174	na
1946	242	17.50
1950	246	17.10
1955	276	17.30
1960	275	17.30
1965	299	28.40
1970	332	29.20
1975	378	32.30
1978	390	32.60
1980	419	69.90
1985	432	88.30
1986	437	88.30
1987	442	88.40
1988	452	88.60
1989	477	89.10

Source: U.S. Department of the Interior, Fish and Wildlife Service. Lands under the control of the Fish and Wildlife Service, summary. Washington, D.C.

Note: na=not available.

Table 63
National Forest System, 1891-1989

Year	Number of units	Land (million acres)	Year	Number of units	Land (million acres)
1891	1	1.24	1950	151	179.69
1895	17	17.93	1955	149	180.3
1900	38	46.52	1960	151	180.84
1905	83	75.35	1965	154	182.14
1910	149	168.03	1970	154	182.57
1915	162	162.77	1975	155	183.28
1920	152	156.03	1980	155	183.06
1925	159	158.40	1982	155	186.56
1930	149	160.09	1984	156	186.38
1935	142	163.31	1986	156	186.46
1940	160	174.77	1988	156	186.25
1945	155	177.64	1989	156	186.91

Source: U.S. Department of Agriculture, Forest Service. Land areas of the National Forest System, as of September 30, 1989. Washington, D.C.

Table 64
National Wilderness Preservation System, 1964-1989

Year	Land (million acres)	Year	Land (million acres)	Year	Land (million acres)
1964	9.24	1973	11.03	1982	79.88
1965	9.24	1974	11.38	1983	80.21
1966	9.24	1975	12.72	1984	88.55
1967	9.24	1976	14.45	1985	88.70
1968	10.03	1977	14.49	1986	88.80
1969	10.19	1978	19.00	1987	88.99
1970	10.40	1979	19.00	1988	90.81
1971	10.40	1980	79.71	1989	91.46
1972	11.03	1981	79.84		

Source: U.S. Department of Agriculture, Forest Service. National Wilderness Preservation System, fact sheet. Washington, D.C.

Table 65
National Wild and Scenic River System, 1968-1989

Year	River miles	Year	River miles	Year	River miles
1968	773	1976	1,610	1984	7,217
1969	773	1977	1,610	1985	7,224
1970	868	1978	2,299	1986	7,363
1971	868	1979	2,299	1987	7,709
1972	895	1980	5,662	1988	9,264
1973	961	1981	6,908	1989	9,281
1974	1,018	1982	6,908		
1975	1,145	1983	6,908		

Source: U.S. Department of the Interior, National Park Service. River mileage classifications for components of the National Wild and Scenic River System, unpublished data. Washington, D.C.

Table 66
National Estuarine Research Reserves and National Marine Sanctuaries, 1975-1989

Year	Estuarine Research Reserves		Marine Sanctuaries	
	Number	Area (acres)	Number	Area (sq. nmi.)
1975	1	4,700	2	101
1976	3	14,205	2	101
1978	4	22,605	2	101
1979	5	216,363	2	101
1980	9	223,426	3	1,353
1981	11	229,652	6	2,323
1982	14	240,571	6	2,323
1984	15	242,121	6	2,323
1986	16	245,149	7	2,324
1988	17	247,348	7	2,324
1989	18	253,477	8	2,721

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Marine and Estuarine Management Division, unpublished data. Washington, D.C.

Note: sq. nmi. = square nautical miles (1 square nautical mile = 1.25 square statute miles = 640 acres).

Table 67
National Register of Historic Places, 1967-1989

Year	Properties listed	Properties removed	Year	Properties listed	Properties removed
1967	873	2	1979	20,589	366
1968	903	3	1980	24,680	403
1969	1,106	4	1981	26,499	406
1970	1,888	19	1982	29,999	420
1971	3,026	51	1983	35,112	434
1972	4,376	93	1984	39,121	440
1973	6,646	144	1985	42,538	445
1974	8,247	188	1986	45,936	452
1975	10,805	231	1987	48,254	525
1976	12,561	265	1988	51,286	574
1977	14,203	290	1989	53,838	635
1978	16,575	338			

Source: U.S. Department of the Interior, National Park Service. The National Register of Historic Places, unpublished data. Washington, D.C.

Table 68
Visits to areas administered by the National Park Service, 1905-1988

(millions)

Year	Visits	Year	Visits	Year	Visits
1905	0.14	1935	7.88	1965	102.71
1910	0.20	1940	16.33	1970	150.84
1915	0.34	1945	6.83	1975	238.85
1920	1.06	1950	29.86	1980	300.32
1925	2.05	1955	52.27	1985	346.19
1930	3.25	1960	65.46	1988	368.00

Source: U.S. Department of the Interior, National Park Service, Statistical Office. National Park statistical abstract, annual. Denver, CO.

Table 69
Population trends for selected permanent resident bird species, 1966-1987

(percent change per year)

	Trend	
Common name	1966-1978	1978-1987
Northern bobwhite	-3.6	-0.8
Great horned owl	0.8	2.0
Downy woodpecker	-0.2	-0.7
Hairy woodpecker	1.8	1.6
Pileated woodpecker	1.2	2.6
Black-capped chickadee	1.8	3.4
Carolina chickadee	0.0	-0.5
Tufted titmouse	-2.0	3.5
Brown-headed nuthatch	-1.9	-3.3
Carolina wren	1.2	5.4
Northern mockingbird	-1.7	0.0
Northern cardinal	-0.9	0.6
House sparrow	-1.4	-1.4

Source: Robbins, C.S., J.R. Sauer, R.S. Greenberg & S. Droege. 1989. Population declines in North American birds that migrate to the neotropics. Proc. Natl. Acad. Sci. 86, pp. 7658-7662.

Table 70
Population trends for selected neotropical migrant bird species, 1966-1987

(percent change per year)

Common name	Trend 1966-1978	1978-1987
Yellow-billed cuckoo	1.8	-5.0
Whip-poor-will	0.6	-0.8
Ruby-throated hummingbird	0.4	1.8
Eastern wood pewee	-2.1	-0.7
Least flycatcher	-1.6	-0.2
Veery	1.6	-2.4
Wood thrush	1.3	-4.0
White-eyed vireo	0.3	-1.2
Red-eyed vireo	2.8	0.2
Tennessee warbler	18.6	-11.6
Blackburnian warbler	1.3	-1.1
American redstart	1.3	-1.2
Prothonotary warbler	4.4	1.1
Ovenbird	1.0	-1.0
Louisiana waterthrush	-1.0	-0.4
Common yellowthroat	0.2	-1.9
Yellow-breasted chat	-4.5	1.2
Scarlet tanager	2.6	-1.2
Rose-breasted grosbeak	6.1	-4.1
Indigo bunting	0.4	-0.7
Northern oriole	2.0	-2.9

Source: Robbins, C.S., J.R. Sauer, R.S. Greenberg & S. Droege. 1989. Population declines in North American birds that migrate to the neotropics. Proc. Natl. Acad. Sci. 86, pp. 7658-7662.

Table 71
Population estimates and indices for selected waterfowl, 1955-1989

	Population estimate			Population indices	
Year	Northern pintail (millions)	Mallard (millions)	Canvasback (thousands)	Canada goose (millions)	Tundra swan (thousands)
1955	9.25	10.35	595	1.28	90
1956	10.12	11.71	692	1.32	39
1957	6.86	10.95	600	1.11	40
1958	6.89	12.90	713	1.22	28
1959	7.23	10.29	481	1.21	28
1960	5.77	8.21	575	1.14	41
1961	4.86	8.29	396	1.49	63
1962	4.30	6.14	385	1.36	39
1963	4.36	7.36	523	1.59	61
1964	4.11	6.97	658	1.52	62
1965	4.30	5.95	505	1.41	54
1966	5.78	7.40	683	1.43	58
1967	5.87	8.21	556	1.66	72
1968	4.23	7.59	557	1.57	46
1969	6.39	8.07	530	1.74	62
1970	7.00	10.38	601	1.93	55
1971	6.29	9.84	441	1.92	58
1972	7.88	9.87	429	2.07	63
1973	5.11	8.78	696	1.99	57
1974	7.17	7.39	493	2.14	64
1975	6.39	8.11	706	2.19	67
1976	6.05	8.64	686	2.41	79
1977	4.97	8.23	702	2.58	76
1978	5.66	7.70	423	2.79	70
1979	6.07	8.44	606	2.41	79
1980	5.42	8.00	688	2.38	60
1981	4.23	6.76	594	2.76	93
1982	4.11	6.68	543	2.23	73
1983	4.09	7.11	528	2.59	86
1984	3.66	5.97	569	2.44	81
1985	2.94	5.48	411	2.76	94
1986	3.20	6.30	442	2.82	91
1987	3.14	6.69	478	2.97	94
1988	2.58	6.55	435	3.13	77
1989	2.47	6.12	488	3.21	91

Source: U.S. Department of the Interior, Fish and Wildlife Service, Office of Migratory Bird Management in conjunction with the Canadian Wildlife Service. 1989 status of waterfowl and fall flight forecast. Washington, D.C.

Notes: Estimates for northern pintail, mallard, and canvasback are for breeding populations. Indices for Canada goose include cackling goose and are based on fall and winter surveys. Indices for tundra swan are for the eastern population and are based on winter surveys. na=not available.

Table 72
Population trends for selected waterfowl, 1966-1988

(percent change per year)

Common name	Trend 1966-1987	1987-1988
Canada goose	7.4	19.6
Wood duck	3.6	-1.5
Mallard	0.9	-4.4
Northern pintail	-6.9	-39.4
Blue-winged teal	-0.8	5.6
Northern shoveler	-1.1	40.0
Gadwall	3.5	86.7

Source: Droege, S. & J.R. Sauer. 1989. North American breeding bird survey, annual summary 1988. Biol. Rep. 89(13), pp. 1-12.

Table 73
Threatened and endangered U.S. wildlife and plants, 1980-1989

(number, cumulative)

Group	Threatened 1980	1985	1987	1989	Endangered 1980	1985	1987	1989
Mammals	3	4	7	6	32	20	50	32
Birds	3	3	10	7	66	59	76	61
Reptiles	10	8	18	14	13	8	15	9
Amphibians	3	3	4	4	5	5	5	6
Fishes	12	14	30	25	34	30	47	49
Snails	5	5	5	6	2	3	3	3
Crustaceans	0	1	1	1	1	3	7	8
Insects	6	4	7	7	7	8	10	10
Arachnids	0	0	0	0	0	0	3	3
Clams	0	0	0	0	23	22	30	34
Plants	7	10	44	42	51	67	158	163
Total	49	52	126	112	234	225	404	378

Source: U.S. Department of the Interior, Fish and Wildlife Service, Division of Endangered Species and Habitat Conservation, unpublished data. Washington, D.C.

Table 74
Population estimates for selected threatened and endangered wildlife populations, 1941-1989

Year	Bald eagle (minimum estimate of nesting pairs)	Whooping crane (number in Texas-Canada flock)	Key deer (number of individuals)
1941	na	16	na
1948	na	30	26
1949	na	34	30
1951	na	25	na
1964	600	42	300
1968	na	50	na
1969	na	56	na
1970	na	57	na
1971	na	59	na
1972	na	51	na
1973	na	49	400
1974	na	49	na
1975	850	57	na
1976	na	69	na
1977	na	72	na
1978	1,000	75	400
1979	1,100	76	na
1985	1,900	97	250
1987	2,100	148	na
1989	2,550	145	e

Source: U.S. Department of the Interior, Fish and Wildlife Service, Division of Endangered Species and Habitat Conservation, unpublished data. 1987. Washington, D.C.

Notes: e=250-300 individuals. na=not available.

Table 75
Municipal solid waste generation and recovery, 1960-1990

Year	Gross discards: Per capita (pounds per day)	Gross discards: Total (million tons)	Materials recovery: Per capita (pounds per day)	Materials recovery: Total (million tons)	Energy recovery (million tons)	Net discards (million tons)
1960	2.65	87.5	0.18	5.8	0	81.7
1965	2.88	102.3	0.17	6.2	0.2	95.9
1970	3.22	120.5	0.21	8.0	0.4	112.1
1975	3.18	125.3	0.23	9.1	0.7	115.5
1980	3.43	142.6	0.32	13.4	2.7	126.5
1985	3.49	152.5	0.35	15.3	7.6	129.7
1990	3.67	167.4	0.40	18.4	13.3	135.7

Source: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Characterization of municipal solid waste in the United States, 1960 to 2000. Prepared by Franklin Associates, Prairie Village, KS.

Notes: Data for 1990 are projections.

Table 76
Municipal solid waste recovered, by waste type, 1960-1990

(percentage of gross discards)

Year	Paper	Glass	Metal	Aluminum	Plastics	Rubber & leather	Textiles	Wood	Food & yard
1960	30.0	7.8	12.3	0.5	0.5	2.1	2.1	3.7	39.4
1965	33.5	8.8	10.6	0.5	1.5	2.3	2.0	3.6	35.4
1970	32.4	11.1	11.3	0.7	2.7	2.7	1.8	3.6	32.0
1975	29.6	11.4	10.6	0.9	3.8	3.2	1.9	3.8	33.2
1980	32.5	11.0	9.0	1.1	5.9	3.2	2.0	3.8	29.7
1985	35.5	8.9	7.8	1.2	2.5	2.0	2.0	3.9	29.4
1990	36.8	8.3	7.6	1.3	2.3	2.0	2.0	3.6	28.2

Source: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Characterization of municipal solid waste in the United States, 1960 to 2000. Prepared by Franklin Associates, Prairie Village, KS.

Notes: Data refer to waste discarded after materials recovery has taken place. Data for 1990 are projections.

Table 77
U.S. production of intermediate and finished synthetic organic chemical products, 1967-1988

Product	Qty	Year								
		1967	1981	1982	1983	1984	1985	1986	1987	1988
Crude coal tar	m gal	na	464	316	284	342	na	169	189	162
Petroleum	b lbs	na	110	93	110	109	105	114	101	112
Cyclic intermediates	b lbs	21	45	38	43	47	46	50	55	58
Dyes	m lbs	206	230	222	244	233	222	236	255	280
Organic pigments	m lbs	53	76	71	78	86	81	89	94	116
Medicinal chemicals	m lbs	180	245	227	233	279	225	264	261	258
Flavor & perfume	m lbs	112	165	156	174	179	152	138	126	162
Plastic & resin	b lbs	14	41	38	44	48	50	52	60	63
Rubber processing	m lbs	264	280	232	293	288	260	324	382	353
Elasticizers	b lbs	4	5	4	4	5	4	4	5	5
Plasticizers	b lbs	1	2	1	2	2	2	2	2	2
Surface-active agents	b lbs	4	5	4	5	6	5	6	6	7
Pesticides	b lbs	1	1	1	1	1	1	1	1	1
Miscellaneous	b lbs	60	117	115	114	116	116	119	123	134

Source: U.S. International Trade Commission. Synthetic organic chemicals: United States production and sales, 1988 and earlier issues. Washington, D.C.

Notes: Qty=Quantity. m gal=million gallons. m lbs=million pounds. b lbs=billion pounds. Petroleum=Primary products from petroleum and natural gas for chemical conversion.

Table 78
U.S. production of selected synthetic organic chemicals, 1950-1988

(billion pounds)

Year	Acrylo-nitrile	Benzene (all grades)	Vinyl (monomer) chlorides	Phthalates (anhydride phthalic)	PCBs
1950	na	na	0.25	0.14	na
1955	0.12	na	0.53	0.21	na
1960	0.23	na	1.04	0.34	0.04
1961	0.25	na	1.04	0.38	0.04
1962	0.36	na	1.31	0.47	0.04
1963	0.46	na	1.44	0.52	0.04
1964	0.59	na	1.62	0.60	0.05
1965	0.77	6.08	2.00	0.68	0.06
1966	0.72	7.02	2.50	0.75	0.07
1967	0.67	7.12	2.42	0.78	0.08
1968	1.02	7.50	2.97	0.84	0.08
1969	1.16	9.01	3.74	0.88	0.08
1970	1.04	8.69	4.04	0.86	0.09
1971	0.98	7.91	4.34	0.98	0.04
1972	1.11	9.20	5.09	1.15	0.04
1973	1.35	10.68	5.35	1.20	0.04
1974	1.41	10.94	5.62	1.21	0.04
1975	1.21	7.52	4.20	0.90	0.03
1976	1.52	10.47	5.68	1.04	0.03
1977	1.65	10.55	5.99	1.20	0.01
1978	1.75	10.94	6.94	1.26	0.00
1979	2.02	12.29	7.54	1.29	0.00
1980	1.83	11.64	6.47	1.05	0.00
1981	2.00	9.84	6.87	1.12	0.00
1982	2.04	7.85	6.50	0.95	0.00
1983	2.15	9.70	6.88	1.15	0.00
1984	2.22	10.00	6.08	1.18	0.00
1985	2.35	10.25	9.46	0.82	0.00
1986	2.31	9.97	8.44	0.86	0.00
1987	2.50	10.86	8.55	1.02	0.00
1988	2.61	11.63	9.06	1.00	0.00

Source: U.S. International Trade Commission. Synthetic organic chemicals, United States production and sales, 1988 and earlier issues. Washington, D.C.

Notes: PCB=Polychlorinated biphenyl. PCB has not been produced since 1978.
na=not available.

1 9 7 0

1 9 9 0

1.0
1.1
1.25
1.4
1.6
2.8
2.5
3.2
2.2
3.6
2.0
4.0
1.8